Millar, Kirsty (2021) *Are elite soccer players being physically prepared for the next level? Physical profiling of elite soccer players: a comparison from youth to professional level.* MSc(R) thesis.

https://theses.gla.ac.uk/82791/

Are Elite Soccer Players being Physically Prepared for the Next Level? Physical Profiling of Elite Soccer Players: A Comparison from Youth to Professional Level.

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BSc (Hons)

Submitted in the fulfilment of the requirements of the degree of:

MSc (Research) Sports Science

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March 2021

Abstract

Progression to top tier soccer is not guaranteed for elite youth soccer players; in fact, there is a substantial attrition rate between youth academy and First Team level. Previous research has investigated the differing physical demands between academy age groups (Buchheit et al. 2010) and between tiers of adult professional soccer (Mohr, 2003). No previous research has combined the two and examined the physical demands between older academy squads and the First Team of an elite club, including the transitional Reserve squad (sometimes referred to as the development squad). The aim of this study was, therefore, to examine the differences in physical profiles across the 2019/20 season between top academy squads, the transitional Reserve team squad, as well as looking into the differing external demands experienced across levels of play, including the transition between the Reserve and First Team squad. The end goal was to determine whether players are being physically prepared to progress to the next level of play. It is important to note data collection across the season was not completed due to the COVID-19 pandemic. Physical profiles were determined using a battery of tests to measure: agility (adapted 505 test), speed (30 m sprint), strength (Nordic Curl), power (CMJ, SJ, HJ) and aerobic capacity (1500 m time-trial (TT)) at the start of the season (October) and mid-season (January). Demands of play, both in training and matches, were established by analysing GPS data collected by 10 Hz Catapult X4 (U16), Catapult Clearsky (U18) and Catapult EVO (Reserve and First Team) GPS devices. The testing results showed a general increase in physical capacities with age, particularly strength and power qualities across both October and January testing timepoints. In October, the U18 and Reserve squad countermovement jump results were 3.57 cm and 5.06 cm greater than the U16 group, respectively. Additionally, bilateral eccentric strength results in October showed the U18 and Reserve squad to be 86.85 N and 161.7 N stronger than the U16 group, respectively. Both of the U16 to Reserve squad differences were deemed significant ($p < 0.05$). The results highlight a greater jump between U16 and U18 level than U18 and Reserve team level, who performed similarly. This is likely due to less opportunity to develop these qualities in a strength and conditioning (S+C) program following maturation. Training and match GPS data displayed similarities in terms of total distance between academy and Reserve team squads, however, a jump in high-speed distance between training and matches was apparent, suggesting players may not be adequately prepared for match-play in training. For example, between August to October, the U18 squad covered 124.66 m over 5 m/s in training compared to 592.83 m in matches, on average. The same trend was also reported in January across the U16 squad. However, it was important to consider the effects of periodisation. Between the Reserve and First Team, the most notable difference was match congestion, as the Reserve team competed in

one match per week compared to between two and three in the First Team. This resulted in an approximate 10 km greater total distance covered in an average week by the First Team. It was suggested that the Reserve squad introduce a ‘bounce game’ mid-week to “bridge the gap” between the two teams. In conclusion, several limitations hindered the validity and reliability of results, therefore, to increase the meaningfulness of results, testing protocols should be more strongly adhered to. The academy squads are on-track to reaching the physical capacities of the Reserve squad through their appropriately loaded S+C programs following maturation. The primary concern highlighted by this study is the discrepancy in match congestion as a player progresses to top tier level, suggesting that Reserve players may not be being physically prepared for First Team level, increasing injury risk, and possibly prevalence.

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Acknowledgements

I would like to thank my supervisor, Mr Nairn Scobie, for his continued support and assistance throughout the year which promoted my professional development. His advice was invaluable throughout the data collection and write-up periods, particularly with the COVID-19 pandemic being an unexpected barrier to overcome. I would also like to thank my second supervisor, Dr Ole Kemi, for his outlook on the direction of this research and particularly for his guidance through the statistical analyses. The COVID-19 pandemic caused considerable disruption to this research. Both of my supervisors massively helped minimise the effects of this disruption, enabling the analysis of this research to continue.

As well as my advisers, I would like to thank all of the players and staff at Celtic Football Club across the Academy, Reserve and First Team for their cooperation and advice throughout the year. A special mention to Jack Nayler, William Currie, Scott Breddy, Shane Seeley, Janice Buchanan, Mark Maxwell and Oliver Morgan for their support and assistance with the testing, GPS data collection and analysis over the course of the season. Despite difficult circumstances working remotely due to the pandemic, I am very thankful to these staff members as they continued to assist with my research and answer any questions I had.

Additionally, I would like to thank the University of Glasgow, particularly the Sports Science Department, for the opportunity to experience the elite environment at Celtic Football Club, whilst working towards an MSc qualification at this prestigious institution. The university have offered steady support throughout this year, despite unforeseen circumstances.

Finally, I would like to thank my friends and family for their continued support across the year. It has been invaluable and very much appreciated during trying times.

Abbreviations

1RM	One-Rep Maximum
CMJ	Countermovement Jump
COD	Change of Direction
COVID-19	Coronavirus Pandemic
EPL	English Premier League
ES	Effect Size
GAS	General Adaptation Syndrome
GPS	Global Positioning System
HJ	Horizontal Jump
HSD	High Speed Distance
IAT	Illinois Agility Test
ICC	Intra-correlation Coefficient
MAS	Maximal Aerobic Speed
MD +1	1 day after a match
MD +2	2 days after a match
MD -1	1 day before a match
MD -2	2 days before a match
MD -3	3 days before a match
MD -4	4 days before a match
NHE	Nordic Hamstring Exercise
NM	Neuromuscular
NSCA	National Strength and Conditioning Association
PHV	Peak Height Velocity
PAP	Post-Activation Potentiation
Res	Reserve Team Squad
RSA	Repeated Sprint Ability
S+C	Strength and Conditioning
SD	Standard Deviation
SEM	Standard Error of Mean
SJ	Squat Jump
SLJ	Single Leg Jump
SPFL	Scottish Premier Football League
SSC	Stretch-Shortening Cycle
SWC	Smallest Worthwhile Change
TT	Time Trial
U16	Under 16 squad

U18	Under 18 Squad
VCMJ	Vertical Countermovement Jump
$\dot{V}O_{2max}$	Maximal Aerobic Capacity

1. Literature Review

1.1 Introduction

Professional soccer clubs are comprised of several tiers: grass roots, youth academy, Reserve squad and First Team level. Training sessions, match intensity and prevalence vary between each tier thus the physical demands on each squad are different. As a player progresses from the youth academy through to First Team level, for example, both training and match intensity are likely to increase, placing more physical demands on the player. To give a player the greatest chance of reaching their full potential, the club as a whole are responsible for mentally and physically preparing them for that next level of play.

A club's vision is to develop grass roots players into premier league soccer players: both from a player development and business perspective. These two aspects of a soccer club go hand-in-hand: selling a homegrown player is a success for the player support staff who have produced a top-tier player, which, in turn, may be a huge profit for the club as a business. A successful youth academy also ensures a continuous flow of players into the First Team and provides incentive to academy players train at their best as their dream of making it to professional level seems more attainable (Radoman and Voia, 2015). The greater the success of a club, the greater capital injected by investors into development providing more opportunity for growth and progression.

Buchheit et al. (2010) examined the increase in demand in youth soccer, where maturation was still a factor. Maturation refers to the process of growth in children to reach adult stature, the most notable period of maturation is after puberty, whereby hormonal and physical changes begin to occur (Lloyd and Oliver, 2014). These changes affect performance in terms of skill development, strength, power and can increase injury risk while a player recalibrates to their increased stature (Faigenbaum et al., 2009). They reported a trend of increasing match performance with age, in terms of total distance covered, high intensity running, sprinting and maximum velocity reached during play. The progressive improvements reported from U13 to U18 age groups in the physical testing of this paper may explain the heightened match intensity with age. This emphasises the need to ensure players are being physically prepared to cope with the greater demands of the next level of play.

Of course, not all players will succeed through the ranks to reach First Team level. Players must be physically and psychologically robust with a high technical proficiency to be noticed by coaches and selected to progress. Physical robustness is a product of the training regime, both on and off the pitch. To evaluate the effectiveness of a training program, training load monitoring and physical testing must take place. Training load monitoring is now an integral part of athlete development as coaches ensure load is optimal to promote maximal performance and minimise fatigue and/or injury. Physical testing gives a snapshot of where the player's physical development stands in terms of the rest of the team and between squads, whilst highlighting any strengths and weakness that need addressed in the following training block. Furthermore, testing results assist coaches in making informed decisions on which players are ready to move up to the next level of play.

Strong physical attributes are important for match-play. Faude, Koch and Meyer (2012) researched the importance of sprinting in a soccer match and found that straight-line sprints are the most common action in the game that leads to goal scoring opportunities, followed by changes of direction and jumps. Hence the importance of power also.

The following review discusses the increased physical demands as a player progresses towards professional level - with a particular focus on key physical qualities: speed, strength, power, agility, and aerobic capacity – and the importance of utilising global positioning systems (GPS) to monitor the increase in demands.

1.2 Training Load Monitoring

Global positioning systems (GPS) are now an integral part of athlete monitoring. They allow greater understanding of the demands faced by an athlete in both training and matches which facilitates training to be tailored to replicate and manage those demands (MacLeod et al., 2009). Other tracking methods do exist, video motion analysis for example. This technique can only track the motion of one player and may take hours to generate the data for analysis whereas GPS devices can track multiple players simultaneously in real-time (Peterson et al. 2009).

GPS systems have revolutionised sport as they play a fundamental role in training session design. The load monitoring that GPS devices allow facilitates the understanding of how players adapt to and recover from training sessions (Bourdon et al. 2017). Team sports do not always have the luxury of individualisation of training to each player and more focus is placed on the team as a whole. However, by tracking each player's training sessions and matches using GPS devices, there is promise for a greater understanding of the dose-response relationship (Weston, 2018) which essentially aims to find the "sweet-spot" in eliciting positive adaptation whilst reducing fatigue and injury risk (Gabbett et al., 2017). The dose-response relationship in a sporting context refers to the association between training load and physiological changes elicited in response to the load, this is widely accepted as one of the principal components of a training program (Fitzpatrick, Hicks and

Hayes, 2018). The dose-response relationship may vary dependent on trainability status of players, suitability of training stimuli and stage of the season (Owen et al., 2012).

In soccer, when comparing the microcycles of youth to professional teams the most obvious difference is match congestion. Professional teams participate in two, sometimes three matches per week, compared with one per week in youth football (Carling et al., 2015; Houtmeyers et al., 2020). This alone will adapt the external load each player and team are exposed to during training sessions to optimise match performance. For professional teams, their primary goal is to maintain performance throughout the season in contrast to youth soccer teams who are constantly seeking to develop both physically and technically. The dose-response relationship will therefore differ between these levels of play: exposing youth players to the same external load as a professional team will likely result in an increased injury prevalence due to the players being exposed to an acute spike in external load (Bowen et al., 2019). Being in adolescence alone puts players at a greater risk of injury compared to professional adult soccer players: injury incidence is high in professional soccer with 2.4 to 9.4 injuries occurring every 1000 hours of exposure (Ekstrand, Hagglund and Walden, 2011; Walden, Hagglund and Ekstrand, 2005) compared to 2.0 to 19.4 injuries per 1000 hours in elite youth soccer players (Junge, Chomiak and Dvorak, 2000; Ergun et al. 2013).

Training load monitoring permits training periodisation in soccer. The premise of training across all sport is to maximise competition performance and success. With this is mind, training can be tapered to optimise performance on matchday and prevent possible overtraining (Morgans et al. 2014).

As mentioned previously, microcycles may vary between squads but also within squads as their week-to-week match schedule changes. This must be taken into consideration when designing each training session to promote optimal performance whilst minimising fatigue and injury risk.

Soccer players train to improve and prepare for the next level of play. The objective measure of training load that GPS devices provide enables the jump between squads to be quantified. For example, the jump between the U16 to U18 squad or Reserve squad to First Team, respectively. Progressive overload is a training principle adopted in sport to ensure athletes will gradually be exposed to a greater load (or dose) to elicit gradual improvements in performance (response) to assist them as they move to the next level (Morgans et al. 2014). The quantification of each training session with GPS devices enables this principle to be applied safely and notifies a coach when a player is physically prepared to move up to the next level of play. Their training plans will be tailored to manage this increase in load as they aim to reach the external load undertaken by the next level of play.

Previous literature has examined the differences in external load experienced by squads of different ages and/or levels of play. This will be discussed in the following sections.

1.3 Physiological Demands of Soccer

Soccer is a demanding intermittent team sport. The demands on each player are influenced by a myriad of factors, including: level of play, physical robustness, technical proficiency, player position, tactics, possession and opposition, amongst others. These factors will vary from match-to-match within a team and more significantly between squads of different standards; for example, an U16 squad to a First Team squad.

Harley et al. (2010) examined the motion analysis of U12-U16 squads in two professional English soccer clubs. Using 5 Hz GPS units, they reported a general increase in physical demands and performance as a player progresses through the age groups. Firstly, older squads were exposed to more match-time as match duration increases through age groups. The FA published their Standard Code of Rules for Youth Competitions and stated the for under 11 and under 12, 30 minutes each half; for under 13 and 14, 35 minutes each half and under 15 and under 16, 40 minutes each half; under 17 and under 18, 45 minutes each half (The Football Association, 2019). Resultantly, older players are inevitably exposed to greater physical demands. The absolute total distance achieved was greater in older squads: the U16 squad covered 7.67 km on average which was 1.7 km more than the U12 squad. In addition, the high-intensity, very-high intensity and sprint distance generally increased in a linear fashion from the U12's to U16's, confirming the increase in intensity with level of play.

Although these differences were evident between younger and older squads, the reliability of results in the Harley et al. (2010) study may be questioned as the match data were collected using 5 Hz GPS devices. Scott, Scott and Kelly (2015) reviewed the literature surrounding reliability and validity of several frequencies of GPS devices and reported that the reliability and validity of 5 Hz devices reduces when recording shorter distances and at faster speeds, regardless of age group. Soccer is a very intermittent sport, with an average sprint distance of 18-20 m (Di Salvo et al. 2010) and each player changing direction and or activity every 4-6 seconds, on average (Krustrup et al. 2005). This highlights concern for the values reported by Harley et al. (2010). The Scott, Scott and Kelly (2015) review also stated that a 10 Hz GPS device is the most valid and reliable for team sports, thus it may not be recommended to compare studies that have obtained data from GPS devices with different sampling rates. However, if the GPS output data were normalised, the differences would be abolished.

Regardless of the accuracy of GPS data, varying maturation stages across the youth squads in the Harley et al. (2010) study likely accounted for some of the differences reported, in addition to match duration differences. It has been suggested that boys reach puberty at approximately 13.5 years old (U14 level) with peak height velocity (PHV) being reached between 13.8 and 14.2 years old, i.e., U14 to U15 level (Stratton et al. 2004). PHV refers to the time during puberty with the fastest increase in stature. This period is often referred to as a “window of opportunity” as an athlete has increased hormone levels that make a player more sensitive and responsive to certain types of training, essentially a period of accelerated adaptation (Lloyd and Oliver, 2012). The 10 m flying times reported by Harley et al. (2010) reflect this enhancement, as seen in the table below. The “flying time” refers to the time taken to cover the 10 – 20 m split in a 20 m sprint. These results were obtained by speed gates placed between 10 m and 20 m in a 20 m sprint.

Table 1: 10 m flying time results between U12 and U16 level in an English Premier League club, as reported by Harley et al. (2010).

	U12	**U13**	**U14**	**U15**	**U16**
Time (s)	1.58 ± 0.10	1.52 ± 0.07	1.51 ± 0.08	1.35 ± 0.09*	1.31 ± 0.06*

*Note: * signifies significant differences to U12, U13 and U14 results (p < 0.001)*

Table 1 illustrates that sprint speed increases with age with the greatest improvements seen in age groups post-PHV where physical training demands can be increased considerably. The U15 and U16 age groups performed significantly better than the younger age groups.

Following Harley et al. (2010), Goto, Morris and Nevill (2015) examined match performance in 81 U11 - U16 elite EPL academy players. They highlighted that the increase in pitch dimensions and duration with level of play encourages increased match demands in older academy squads, with more time and space to move. It is common for duration and pitch dimensions to be controlled to reduce the physical demands for younger age groups and control their rate of development and injury risk. However, these papers do not examine the differences in match demands across older academy squads, where pitch dimensions and match duration are kept constant and growth-maturation, or PHV, is no longer a factor.

Many studies have examined similar variables to Harley et al. (2010) in top-tier soccer, where growth and/or maturation is not a factor. They report the typical total distance covered in a top-level match is between 10 and 13 km, though a considerable proportion of that distance is made up of low-intensity movements (Bangsbo, Norregaard and Thorsoe, 1991; Mohr et al. 2003; Krustrup et al. 2005; Bangsbo, Mohr and Krustrup., 2006; Di Mascio & Bradley, 2013). This signifies a minimum of 2 km additional total distance covered by top tier soccer players compared to the U16 squad reported by Harley et al. (2010). It is therefore apparent that the progression and development between these two squads is essential to physically prepare players to eventually reach top-tier level, yet limited literature exists in this area.

In addition to the jump in physical demands between age groups, Mohr (2003) identified the amount of high-speed running in matches as the differing factor between tiers of professional adult soccer: international top-class players performed 28 % more high intensity running and 58 % more sprinting than professional players at a lower level. These findings coincide with those of Harley et al. (2010) as the U16 age group covered 22 % more high-intensity distance than the U12 age-group, confirming that high-speed elements of match-play are a discriminating factor between levels of play.

As previously stated, match congestion varies between squads though particularly between the Reserve and First Team of a club. Brink et al. (2010) underlined the importance of ensuring a gradual increase in training and match load for elite youth players to avoid a sudden increase in physical demands as they transition to First Team level. A lack of literature is available in this area thus little is known about the weekly load differences between the respective teams. Houtmeyers et al. (2020) addressed this by examining the differences in weekly load between the U19 and First Team within a professional club. The U19 squad competed in one match per week, their weekly load was compared against the First Team when they had one and two matches per week. They found the U19 squad to have a lower weekly external load and intensity as well as less training intensity variation, most likely due to less match-time. This study suggested incorporating match-play or high-intensity training sessions mid-week to provide a stepping-stone to First Team level.

Evidently a jump exists between academy and First Team level, emphasizing the need to physically prepare players for the next level of play. A study by Le Gall et al. (2010) reported a correlation between U14 - U16 academy player 40 m sprint times and players who went on to gain an international cap and/or professional contract compared to those who achieved neither. Thus, although technical proficiency and tactical intelligence are a necessity to play in top-tier soccer, the physical capacities of a player are also imperative to achieve that success.

Countless hours go into the development and preparation of elite athletes behind the scenes by the athlete and player support staff. Athlete monitoring has become a fundamental component of this preparation (McGuigan, 2017). Monitoring is valuable to both the athlete and practitioner as it evaluates a player’s progress and the effectiveness of the training program in place.

Training is designed to improve athletic performance, whether that be technical proficiency or physical attributes. To assess whether training has elicited a physical improvement, testing is carried out. For this research, tests were selected to assess several key physical attributes: strength, power, speed, aerobic capacity and agility.

1.4 Physiological Testing

In elite sport, testing is considered essential prior to the start of a competitive season or a strength and conditioning program (Turner et al. 2011). By assessing a player's progress through an identical battery of testing throughout the season, evaluation of training programs can be carried out as well as identifying key areas of improvement that can be targeted in the next training block. In soccer, there is limited time to test due to the busy training and match schedules of squads. It is also important to gain coach 'buy-in' so that they support and value the testing undertaken.

1.4.1 Strength

Soccer players must be strong, yet explosive on the pitch to perform fast, powerful movements efficiently. This balance between strength and speed is essential, as carrying too much muscle mass may slow a player down. Thus, large muscle mass, often associated with strength, is not always a good thing. Nonetheless, an elite soccer player must maintain high strength levels throughout the season to withstand pressure put on them by the opposition and to generate force and power to gain a competitive advantage.

In addition to generating force and power, muscular strength is crucial for injury prevention (Askling et al., 2003). Hamstring injuries are recognised as the most prevalent injury in soccer due to the high eccentric demands experienced by players to generate speed and power, at both amateur (van Beijsterveldt et al., 2015) and professional level (Ekstrand Hägglund and Waldén, 2011; Hawkins et al. 2001). Ekstrand and Gillquist (1983) reported 80 % of muscle strains in soccer players were in the lower limbs: 47 % of those in the hamstrings. Stanton and Purdam (1989) recommended strength training to be a preventative measure for hamstring injuries. The Nordic Hamstring Exercise (NHE) is thought of as the best hamstring strength exercise as it targets eccentric knee flexor strength and muscle architecture. This exercise is well-known throughout the football community, with 88 % of European teams acknowledging its importance (Bahr et al., 2015) and is a top-ranked injury prevention exercise by practitioners (McCall et al., 2014). More recent studies are still investigating the findings of Stantom and Purdam in 1989, as it has been reported that chronic NHE programs reduce hamstring injury prevalence by 57 – 72 % in soccer players, regardless of age or level of play (Arnason et al., 2008; Mjølsnes et al., 2004; Petersen et al., 2011).

Strength can be measured in a variety of ways, the one-repetition maximum (1RM) test is considered the gold-standard test (Levinger et al., 2009). This method of strength testing has been proven to be both valid and reliable across numerous populations, including adolescents (Faigenbaum et al., 2012) and trained and untrained adults (Seo et al., 2012; Ribeiro et al., 2014; Urquhart et al., 2015). A 1RM test can be performed using several exercises such as a back squat, bench press, shoulder press or deadlift. It is important to select the test that is most relevant to the sport: in soccer, lower body strength is the most important thus the back squat would be more appropriate. However, lifting maximal weight is not safe for individuals who are not familiar with weight training due to the high injury risk and muscle soreness experienced (Braith et al. 1993; Dohoney et al. 2002), therefore the 1RM may not always be appropriate.

Recent technological advances have enabled hamstring strength to be measured directly; one such device is the NordBord by VALD Performance. This device enables both eccentric and isometric strength to be measured using the NHE directly: the most common eccentric hamstring strengthening exercise (Lodge et al. 2020). Lower eccentric hamstring strength is associated with increased risk of non-contact anterior cruciate ligament injures and a fourfold increase of total hamstring injuries (Opar et al. 2013) making it an important test for players. This eccentric measurement may assist player selection, return to play timelines and injury risk assessments.

A study by Lodge et al. (2020) reviewed the reliability and validity of the NordBord against an isokinetic dynamometer and reported high test-retest reliability (ICC = 0.91) and good validity (ICC = 0.82).

Age-related differences in athlete strength capacities have been reported previously. Gür et al. (1999) reported an improvement in maximal concentric (quadricep) and eccentric (hamstring) isokinetic muscle strength in players over 21 years of age, compared to those under 21 years. Buchanan and Vardaxis (2003) also reported an increase in relative hamstring and quadricep strength in youth basketball players: the 15 - 17-year-old age group exhibited greater strength than the 11 - 13-year-old group.

Based on these findings and the importance of strength in soccer, this was a relevant characteristic to examine between age groups in this study and determine whether players were strong enough to progress to the next level of play.

1.4.2 Power

Power is another fundamental athletic attribute. Defined as a combination of strength and speed, power is notably important in actions that require fast movements, such as: kicking, sprinting, tackling and jumping. In a professional match, a player changes direction approximately 1100 times (Andrzejewski et al., 2015). Dependent on the team formation and player position, a player may change activity every 4-6 seconds (Krustrup et al., 2005). Each turn and activity must be performed quickly to gain advantage over the opposition, highlighting the importance of power. In general, the greater the power generated in an action, the faster and greater the outcome. For example, when taking a shot on goal, the more power generated in a leg swing, the more force transferred to the ball, giving the goalkeeper less reaction time to make the save.

As stated, power is ‘speed x strength’; however, Verkhoshansky (1966) stated that two subtypes of power exist: strength-speed and speed-strength and it is important to distinguish which subtype is most relevant to the sport of the athlete when assessing their power capacities. These subtypes lie on separate areas of the force-velocity curve and so should be trained and tested differently. Soccer is a very quick, explosive sport making speed-strength the most relevant to measure.

Resultantly, as a soccer player is unlikely to have to exert maximum strength in a game and is likely to perform multiple fast-powerful movements, a CMJ would be more appropriate to measure lower body power as opposed to a 1RM power clean (Harman and Garhammer, 2008).

Young, MacDonald and Flowers (2001) found the vertical jump an appropriate method to assess lower body strength and power as vertical jump height has been proven to relate to both maximum strength and power in the lower limbs, when the upper limbs are restricted. The vertical jump height is influenced by multiple factors including the speed and amplitude of the countermovement (Bosco and Komi, 1981), and the efficiency of the transition from eccentric to concentric phases of the jump (Ashley and Weiss, 1994). These factors collectively produce jump performance which many authors accept to represent leg muscle power (Adams et al., 1992; Bauer, Thayer and Baras, 1990; Coutts, 1976; Venable et al., 1991).

Other studies have reported the squat jump and countermovement jump to be the most valid and reliable field tests in terms of lower body power assessment (Markovic et al., 2004). Markovic et al. (2004) reported these jumps to have a reliability, measured using Cronbach’s alpha, of 0.97 and 0.98, respectively. The CMJ also showed the highest validity, indicated by a correlation (r) of 0.87 with the principal component identified across seven different jump tests, which was referred to as the explosive power.

The National Strength and Conditioning Association (NSCA) recommends the standing long jump as a field test of horizontal power. The test is easy to administer with low equipment requirements making it a feasible test to perform with large squads. Power can also be measured in a laboratory on a watt bike using the Wingate anaerobic cycling test which consists of a 30-second maximal effort against a pre-set resistance. However, the Wingate test may not be as relevant as the vertical and horizontal jumps as a player will rarely perform maximally for 30 seconds non-stop, as approximately 96 % of sprints in a match are less than 30 m with an average duration of less than six seconds (Bangsbo, 1994).

Power is a well-documented area of literature in soccer, underlining its importance in the game. Previous research has investigated the relationship between playing level and the ability to generate power. Haugen, Tonnessen and Seiler (2012) examined the effect of both age and level of play on power-generation capacity in elite female soccer players using the CMJ. They reported an increase of around 8 % in CMJ height between players under 18 and players over 25, who played at a more elite level.Furthermore, Gerodimos et al. (2006) demonstrated a 34 % increase in CMJ height between 10- and 17-year-old elite youth soccer players, illustrating a strong increase in power-generation capacity. The oldest players in this study, the 17-year old's, had an average CMJ height of 35.2 ± 5.1 cm; a study by Krommes et al. (2017) reported the average CMJ results of top professional Danish soccer players to be 44.47 ± 5.38 cm. Although, of course, there are limitations within this comparison due to players coming from different clubs, inter-tester variability as well as timeframes, there is a clear discrepancy between youth and professional soccer players, highlighting the need for players to be progressively overloaded in training to progress to the next level of play.

In addition to testing maximal power capacity in athletes, the CMJ can also be utilised to understand the physiological impact of a training stimulus (Halson and Jeukendrup). Jumping ability can be a marker of fatigue as impaired jumping performance may indicate a decline in neuromuscular status as result of repeated exercise over consecutive days. This may also be used to quantify and compare fatigue levels following different training regimes to determine the optimum training regime to produce peak performance on match-days. Malone et al. (2015) examined the change in CMJ performance in professional soccer players across a microcycle during the in-season. They measured jump performance before and after four consecutive training sessions of an in-season microcycle and examined the results against GPS data from the training sessions. Their findings displayed no significant effect of a training microcycle on CMJ performance, suggesting that soccer players can maintain jumping ability in-season.

Power testing evidently has been at the forefront of many studies as it plays a profound role across multiple sports. Its importance and relevance in soccer, as well as the research examining age-related differences, justifies its inclusion in this study.

1.4.3 Speed and Acceleration

Speed is another relevant characteristic to measure and can be defined as the time it takes to cover a set distance. Soccer requires repeated high-speed actions which an athlete must be physically capable of performing. The high-speed efforts are intermittent with lower intensity activities. Reilly, Drust and Clarke (2008) reported players to perform a high-intensity action every 60 seconds, on average. Furthermore, Di Salvo et al. (2007) found that players may perform up to 40 sprints in a match, signifying the importance of speed to gain advantage over the opposition. As previously mentioned, Faude et al. (2012) highlighted the action in a match with the strongest correlation with goal-scoring opportunities is linear-sprint speed, underlining its importance in the game.

The average sprint distance of a team-sport athlete is 15-21 m (Andrzewjewski et al., 2013, 2015; Gabbett, 2012). Team sport players rarely sprint over 20 m in a match, therefore Ellis et al. (2000) recommended measuring speed over this distance. However, it is likely that this would represent acceleration and not speed. With a non-stationary start, peak speed may be achieved around 28.7 m (Young et al., 2008) thus a 30 m sprint would be sufficient to measure peak speed. Young et al. (2008) proved that a valid method to measure peak speed in a 30 m sprint is to divide the 10 m distance by the time taken to sprint between the 20 m and 30 m speed gates, i.e., the flying time.

Many studies have utilised different methods to assess maximum speed, though the majority measure with linear running over 5 to 40 m (Chamari et al., 2004; Little and Williams, 2005; Mirkov et al., 2008; Sayers, Sayers and Binkley, 2008, Taskin, 2008). Turner et al. (2011) stated that acceleration can be measured as the time taken to complete a 5 to 10 m sprint from a stationary start which has been proven to be both valid and reliable.

The literature in this area acknowledges the time constraints and other limitations, such as weather and equipment availability, in a practical setting and recommends measuring acceleration and speed in the same test by placing speed gates in 10 m splits for efficiency (Turner et al., 2011). They also suggest three repetitions of the sprint (Chamari et al., 2004; Mirkov et al., 2008; Sayers et al., 2008) with 5 minutes recovery in-between for validity and reliability (Dupont, Akakpo and Berthoin, 2004). Altmann et al. (2017) found that the height of timing gates has further effect on the validity of sprint testing: they reported that sprint times differed significantly between timing gates of 0.64 m and

0.25 m and when compared against a high-speed video camera, both heights were not valid over distances less than 30 m.

Regardless of limitations in a practical setting, many studies have looked into how sprint capacities change with an athlete's level of 'eliteness'. The results of Harley et al. (2010) discussed previously and displayed in table 1, highlighted a progressive improvement with increasing age group. These findings may be backed up by Williams, Oliver and Faulkner (2011) who found a linear decrease in 30 m sprint time, alongside a linear increase in vertical jump height in U12 to U16 players, indicating a correlation between speed and power. The fastest 10 m flying time reported by Harley et al. (2010) was an average of 1.31 ± 0.06 s by the U16 squad. Although this study didn't include First Team data to compare to, Wisloff et al. (2004) reported the 10 m and 20 m split times within a 30 m sprint for a Norwegian Champions League team, which, when calculated, covered the 10 m distance in 1.18 ± 0.3 s. This underlines the increase in physical performance between elite youth and professional soccer.

Sprinting is undoubtedly key in soccer to outperform the opposition and maintain a competitive advantage throughout. Evidently, an increase in sprint performance is required to progress to the next level of play and so may assist in determining whether a player is ready to progress.

1.4.4 Aerobic Capacity

Aerobic capacity is the ability for the heart and lungs to oxygenate working muscles. Although soccer is intermittent in nature and not entirely reliant on a player's aerobic capacity, the requirement to possess a high repeated sprint ability (RSA) demands a high aerobic capacity to optimise recovery time between sprints. As level of play increases in professional soccer, the percentage of high-intensity running and sprinting in a match increases (Mohr, Krustrup and Bangsbo, 2003). Therefore, the speed of recovery from sprints becomes increasingly important as a player becomes more elite. Sprinting is fuelled by immediate phosphocreatine stores, thus RSA relies on the speed of phosphocreatine resynthesis and removal of hydrogen ions hindering muscular performance. Aziz, Chia and Teh (2000) found aerobic capacity to assist RSA by increasing the ability of muscles to buffer hindering metabolites and promote phosphocreatine resynthesis from inorganic phosphates post-exercise.

Castagna et al. (2006) reported that running economy, maximal aerobic capacity (VO_{2max}) and lactate threshold are positively correlated to match performance, in terms of distance, time on the ball and number of sprints performed. Wisloff et al. (2004) also reported that with an increased VO_{2max}, overall team success increases, i.e., the final league standing, in professional soccer. The correlations of aerobic capacity with match performance make it an essential physical quality in soccer.

Several tests exist to measure aerobic capacity: the 20m PST and the Yo-Yo intermittent test are both commonly used in team sport settings. Both tests include a 20 m shuttle run, though they differ in that the Yo-Yo test includes a recovery period after the 2 x 20 m shuttle run. As soccer is an intermittent sport, the Yo-Yo test more accurately represents the demands as opposed to a continuous beep test as it tests the ability to repeatedly perform high-intensity aerobic work (Bangsbo, Iaia & Krustrup, 2008). There are two primary variations of the Yo-Yo test: the Yo-Yo intermittent recovery level 1 (YYIR1) starts a slower speed (10 km/h) and is more appropriate for younger or recreational athletes with a lower aerobic capacity. The YYRI2 is designed for elite athletes with a higher aerobic capacity as it begins at a higher speed (13 km/h) (Fanchini et al., 2014).

Another method of testing aerobic capacity is by measuring maximum aerobic speed (MAS). MAS is the slowest pace at which an individual reaches VO_{2max} (Bosquet, Leger and Legros, 2002). MAS is useful to measure improvements in physical fitness and prescribe training programs (Dupont et al, 2002). It has been reported that the optimal training to maximise the time spent at VO_{2max} is interval training (15 s on, 15 s off) at 120 % MAS, as opposed to continuous training at 100% MAS or interval training at other MAS intensities. Greater exposure at VO_{2max} elicits greater VO_{2max} improvements (Bompa and Bompa, 1999).

MAS must be assessed to set these intensities and can be measured in several ways, including: a graded exercise test or a set-distance time-trial (TT). A set-distance TT requires minimal equipment and staffing therefore may be the most feasible in a practical environment. Bellenger et al. (2015) compared the predicted MAS values attained from several distances of TT to the traditional MAS protocols. They reported that MAS prediction from the average speed during a TT of between 1200 to 2200 m was valid and reliable, with the 2000 m TT showing the highest correlation with MAS. Previous research suggested that the duration and distance to hold VO_{2max} or MAS is 333- 522 seconds or 1669-2009 m (Lacour, Montmayeur and Dormois, 1989; Billat et al., 1995, 1999; Dupont et al. 2002), respectively, therefore the findings of Bellenger et al. (2015) coincide with this.

One of the many benefits aerobic capacity can provide to performance is to improve RSA. Chamari et al. (2004) reported a significant 0.85 L/min increase in VO_{2max} between youth and adult soccer players from 3.6 L/min to 4.45 L/min, indicating an increase in aerobic capacity is required to play at a more elite level. Not measuring aerobic capacity directly, Mujika et al. (2009) reported an increase in RSA between U12 and U18 age groups in youth soccer players, which was likely encouraged by increased aerobic capacity, although this was not reported. Jones et al. (2013) directly investigated the relationship between VO_{2max}, i.e., aerobic capacity, and mean and total sprint time, i.e. RSA, of 6 x 40 m sprints. They reported a significant negative correlation between VO_{2max} and mean sprint time and total sprint time, concluding that an increase in aerobic capacity increased RSA.

Slimani et al. (2019) performed a meta-analysis of the VO_{2max} characteristics of male soccer players relative to their competitive level and age group. Their results showed aerobic capacity increased significantly from youth to professional level as the demands of the game increase. The meta-analysis concluded aerobic performance to be fundamental to soccer and accurately distinguishes lower and higher-level players.

Evidently a trend exists between aerobic capacity and level of play, therefore it was important to examine its role in athlete preparedness for progressing towards top-tier soccer.

1.4.5 Agility

As previously mentioned, a soccer player changes direction very frequently in a game (Harman et al., 1990), these movements may be described as agility-based actions. Agility is the ability to move quickly and effectively in response to a stimulus (Harman et al., 1990), thus is essential in tight spaces. In youth athletes, agility is recognised as one of the fundamental factors in the future success of 11-year-old athletes (Mirkov et al., 2010). Resultantly, training programs implemented in team sports incorporate change of direction (COD) exercises to improve overall athleticism.

Straight-line sprinting, strength and power are all physical attributes that influence COD ability (Sheppard and Young, 2006). COD ability has also shown to discriminate between elite and non-elite young soccer players, indicating level of play affects results (Young, Dawson and Henry, 2015). To the authors knowledge, there is no gold standard test for measuring COD ability however the traditional test to quantify COD ability is the 505-test.

The 505 test involves players accelerating from a standing start for 5 m, turning 180 degrees and accelerating back 5 m to the start line. Draper and Lancaster (1985) reported this test to be a valid measure of COD as results are consistent regardless of running speed. Draper and Lancaster (1985) also reported the 505-test to be more valid than the Illinois Agility Test (IAT), which showed stronger correlations with top speed than COD ability. However, Sayers (2015) questioned the 505-test validity for two reasons: the 505-test was more of a measure of COD than true agility and the 5 m sprint was too long resulting in linear running speed influencing the results. Despite the doubt expressed by Sayers (2015), Draper and Lancaster (1985) reported the value of the 505-test to be in the deceleration and re-acceleration in the COD and that the 5 m distance was more a representation of acceleration than top speed. In a soccer match, a player will change direction countless times, and the speed at which they can accelerate in another direction is likely to decide which player will reach the ball first, making the 505-test appropriate in soccer.

As stated, the 505-test consists of a participant acceleration in a straight-line for 5 m, to the marked cone, turning 180 degrees and accelerating back to the line at which they started: the results are based on time. For accuracy, speed gates may be used rather than a manual stopwatch to eliminate human error and reaction time.

Most literature employs the 505-test to measure COD ability, likely due to its simplicity. Sonesson, Lindblom and Hagglund (2020) measured age-related differences in the 505 results and reported a significant increase in performance from players aged 13 to 16 years old. This study lacked data on players above 16 years old; however, Kadlubowski et al. (2019) tested U17 to U23 elite soccer players from a professional German club. This study was limited in that the results were combined to give an overview of all the players and did not break the results down into age groups. However, the small standard deviation suggests players performed similarly, with the average performance being 2.17 ± 0.06 s. Valid comparisons between these studies is difficult due to players being from different clubs, inter-tester variability and testing conditions likely influencing results. However, on basic level, the results suggest that a larger improvement in change of direction ability is apparent between pre-pubertal squads and less variation exists when maturation is less of a factor.

An increase in agility capacity assists in soccer players coping with the countless changes of direction they encounter in a match. Adding this physical quality will strengthen an athlete's physical profile and likely increase their chances of succeeding to professional level.

1.5 Conclusion and Aims

It is evident that the existing literature views youth and top tier elite soccer players as separate entities and rarely looks at the preparedness of players to move up to the next level of play. This study aims to examine this gap between academy and First Team soccer and determine whether players are being physically prepared to progress to the next level of soccer. Both physical testing and GPS data will be examined to decide this.

Firstly, this study aims to examine the physical testing results at each timepoint to determine the leap in physical ability between the academy squads and Reserve squad.

Secondly, this study aims to determine whether players are being prepared in pitch sessions, using GPS data collected from training and matches, to cope with the demands of play at the next level, i.e., age groups.

Finally, this study aims to examine the preparedness of Reserve squad players to progress to First Team level and the primary differences between these squads.

2. Methods

2.1 Participants

This study collected data from 34 elite male youth soccer players (U16: n=17; U18: n=17), 20 professional Reserve and 20 First Team players of an elite Scottish Premier League Club (see table 2). The data were collected over the 2019/20 SPFL season. Unfortunately, due to the COVID-19 pandemic, data collection ceased prematurely.

Table 2: Physical characteristics of the study participants in each squad (U16, U18, Reserve and First Team).

Squad	Age (years)	Height (cm)	Weight (kg)
U16	15.33 ± 0.21	172.69 ± 8.63	59.98 ± 5.55
U18	16.57 ± 0.67	180.27 ± 6.01	68.72 ± 5.73
Reserve	18.43 ± 1.03	177.69 ± 5.37	73.72 ± 6.44
First Team	25.19 ± 3.88	181.40 ± 7.87	78.05 ± 7.43

Note: Values displayed as Mean ± SD.

Players in the U16 squad were still at school and participated in four pitch training days per week, two S+C sessions using bodyweight exercises and one match per week, leaving two rest days (one being MD +2). As these players were still at school, they often had more than one pitch session per day, with an outdoor skills session in the morning, a training session in the evening that sometimes included a fitness session. The U18 squad were full-time and participated in five pitch training days per week (one recovery post-match), with three S+C sessions per week, using weights, and one match per week leaving one rest day. Their number of pitch sessions per day also varied as they trained at three different locations on different surfaces, often all in the same day. The number of pitch sessions varied day-to-day but also week to week; i.e. a MD -3 day did not always have the same number of pitch sessions and not all players participated in the sessions out with the main training session of the day, thus the additional sessions did not represent the training load of the squad as a whole.

Reserve squad players participated in five training days per week (one recovery post-match), with four S+C sessions built-in to increase strength and power, one match per week, leaving one rest day. The squad participated in one pitch session per day.

Table 3 below illustrates the general structure of training for squads in a typical week.

Table 3: Typical Week Schedules for the U16, U18 and Reserve Team squads.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
U16	Off	MD +2	MD -4	MD -3	MD -2	MD -1	Match
U18	MD -4	MD -3	MD -2	MD -1	Match	Recovery	Off
Res	MD -1	Match	Recovery	Off	MD -4	MD -3	MD -2

The First Team weekly training schedule was adapted to manage match congestion, as they partake in two to three matches per week; S+C work was optional for them.

All participants were informed of what the study involved and provided written consent to partake, this was provided by player and parents/guardians for the U16 squad. The University of Glasgow Ethics Committee granted ethical approval for this study’s procedures.

2.2 Experimental Design

With the players involvement with Celtic FC, they are required to wear GPS units for all training sessions and matches. Between squads, different GPS units were worn: the First Team and Reserve squad wore Catapult EVO units (manufactured in Leeds, United Kingdom); the U18 squad wore Catapult Clearsky units and the U16 squad wore Catapult X4 GPS units, all of which operate at a sampling frequency of 10 Hz.

Participants were to be tested within their squads at three timepoints throughout the year: the beginning of October (start of the season), January (mid-season, following the Christmas break) and May (end of the season). Training blocks, or mesocycles, were between August to October and October to January, at which points physical testing took place to assess the progress of each player and therefore, the effectiveness of the training program. GPS data could be analysed in each mesocycle to compliment and provide insight into the physiological testing results. However, due to the suspension of all soccer activities because of the Coronavirus pandemic, and several other limitations, the academy’s second set of testing was not completed, and the May testing period was cancelled entirely. The table below illustrates the physical testing data that were able to be collected.

Table 4: Physical testing data collected throughout the season.

Timepoint	*Measure*	**U16**	**U18**	**Reserve**
Oct	**Speed**	Y	Y	Y
	Strength	Y	Y	Y
	Power	Y	Y	Y
	Aerobic Capacity	Y	Y	Y
Jan	**Speed**	Y	Y	Y
	Strength	Y	Y	Y
	Power	Y	Y	Y
	Aerobic Capacity	N	N	Y
May	**Speed**	N	N	N
	Strength	N	N	N
	Power	N	N	N
	Aerobic Capacity	N	N	N

The testing protocols were employed to assess strength, speed, agility, power and aerobic capacity. Across the squads, identical protocols were used to assess each physical characteristic.

Testing was carried out following a warm-up consisting of 5 minutes on a spin-bike, 10 linear and lateral leg swings on each side, 10 bodyweight squats, 5 single leg hip thrusts on each side, 5 maximal CMJ's and 10 pogo ankle jumps. Participants were verbally encouraged throughout testing.

The stations were performed as described in the following sections.

2.3 Physiological Testing Methodology

Testing was carried out following a recovery day to ensure results were not hindered by muscular fatigue. The following testing battery was implemented in both October and January for the U16, U18 and Reserve squads to show inter-squad and across-season differences. Testing was carried out in the most time-efficient way due to limited allocated time, thus the order of tests was not kept consistent, nor was the time of day of testing.

2.3.1 Strength

Hamstring strength was measured both isometrically and eccentrically using a NordBord by VALD performance (manufactured in Queensland, Australia). To assess isometric hamstring strength, participants were in a prone position with the ankle braces of the device sat immediately above the back of the participants footwear, across the Achilles tendon. Participants were instructed to make 3 bilateral maximal isometric hamstring contractions by pulling the ankle braces of the NordBord hamstring testing device in an upward direction. Three 3-second maximal efforts were completed to measure the isometric hamstring strength, with 15-20 seconds rest between efforts to replenish immediate energy stores. The greatest force value (N) of the 3 efforts was used for analysis.

Eccentric strength was assessed by performing a bilateral Nordic Curl on the same testing device. This was performed as described by Opar et al. (2013). Similarly, participants performed one set of three maximal repetitions with the maximal value being used for analysis.

As previously mentioned, Lodge et al. (2020) established a high test-retest reliability (ICC = 0.91) of the NordBord and good validity (ICC = 0.82).

2.3.2 Power

Several jumps were carried out on Forcedecks force plates (manufactured in London, UK) to assess power, including vertical countermovement (VCMJ) and squat (SJ) jumps, as well as single leg jumps (SLJ). Bilateral and unilateral horizontal jumps (HJ) were performed and measured manually using a measuring tape. For all jumps: If the participant achieved their best jump in their 3rd attempt, they continued to jump until no further improvement was seen to achieve as close to a true maximum as possible. A large improvement seen over the 3 attempts or more, suggested a poor warm-up.

Vertical Countermovement Jump (VCMJ)

The VCMJ protocol involved hands on hips and 3 maximal bilateral efforts. Participants were instructed to jump as high as possible, at whatever depth of jump that required. Prior to testing on the force platforms, each participant had 3 practice jumps. Rest periods of 15-20 seconds between jumps allowed sufficient recovery time to replenish energy stores.

Slinde et al. (2008) reported this test to have a high test-retest reliability with an ICC of 0.93.

Squat Jump (SJ)

The SJ was also performed with hands on hips with 3 maximal efforts. It differed from the CMJ as the participant started in a squat position at a 90-degree angle for 3 seconds before jumping vertically on the force platforms. It was important that the participant did not dip lower in the squat to jump, as this would more closely resemble a CMJ. If participants did dip lower prior to jumping, they were asked to perform another jump correctly, moving only upward from the squat position.

Watkins et al. (2020) reported a high test-retest reliability of (ICC) 0.99 for the squat jump.

Single Leg Jump (SLJ)

With hands on hips, participants performed 3 maximal unilateral vertical jumps on each leg on the force platforms. Participants took off and landed on the same leg, the free leg was lifted at a 90-degree angle and did not touch the floor at any point. Between repetitions, 15-20-second rest periods allowed sufficient recovery.

The test-retest reliability (ICC) of this method was found to be between 0.91 to 0.96 for women and men, respectively (Meylan et al., 2009).

Horizontal Jump (HJ)

Participants started with toes behind the line, hands on hips and jumped as far forward as they could. This jump was performed both bilaterally and unilaterally. Each jump had 3 repetitions and the best value was used for analysis. The jump measurement was taken from the line to the shortest part of their jump (i.e., the heel of the back foot). The medial surfaces of the knees were not allowed to cross or pass-by each other in the unilateral efforts to minimise momentum-generation in the swing that may falsely increase jump distance. If knees crossed, or there was any movement on landing, the jump was discounted, and participants were asked to jump again.

Meylan et al. (2009) reported the test-retest reliability of this method to be (ICC) 0.97 in men and 0.95 in women.

2.3.3 Speed

SmartSpeed speed gates (manufactured in Nottingham, UK) were used to measure speed over 10, 20 and 30 m distances. The sprint started 1 m behind the first set of speed gates that were set at ‘0 m’. Each player sprinted the 30 m distance 3 times and their best sprint time was used for the analysis. The sprint lasted approximately 4 seconds, with roughly 3.5 minutes rest between sprints for each player: the time taken to get from the back to the front of the queue, ensuring full recovery between sprints.

Maximum velocity was calculated by the following equation:

$$\frac{10}{30\ m\ (s) - 20\ m\ (s)}$$ (Young et al., 2008)

The time taken to cover the 10 m distance between the 20 m and 30 m speed gates represents the fastest running period (flying time) and not acceleration (Young et al., 2008).

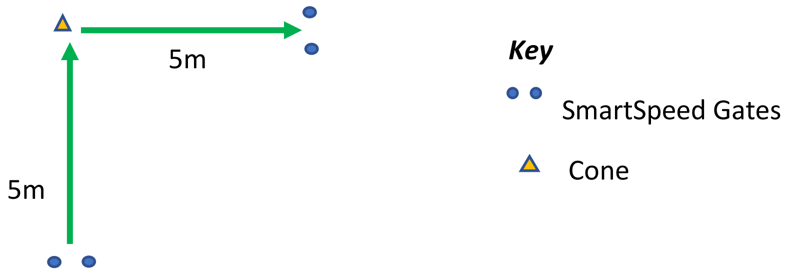
Average velocity was calculated by the following equation:

$$\frac{30}{\textit{Time taken to cover 30 m (s)}}$$

2.3.4 Agility

Agility was measured using a modified 505 test, illustrated in figure 1. The test encompassed players running straight for 5 m, turning at a 90° angle around a cone to run another 5 m as fast as possible. This test was also measured using SmartSpeed speed gates which were placed at the start and end points of the test as shown below.

Figure 1: The design of the modified 505 agility test.



Participants were instructed to get from the start to finish as fast as possible, going around the cone at the 90° angle. If the participant did not go around the cone, the time was scrapped, and the participant performed again.

This is a modification of the standard 505 test which encompasses a 180° turn, not a 90° turn as seen in this study. This was adapted by Morgan (2019) as players are likely to turn 90° in a match more regularly than 180°, hence the 90° 505 test may be more appropriate. Fifty-three participants aged U14 to Reserve team level partook in the study to determine the test reliability and ability to detect change. The intra-correlation coefficient of this test was 0.85 in the right direction and 0.93 in the left direction, proving good to excellent reliability (Hopkins, 2000). Liow and Hopkins (2003) proposed that when $SEM \leq SWC$, ability to detect change is good, which this study exhibited.

As this test was proven to be both reliable and able to detect change by Morgan (2019), it was used for agility testing in this study.

2.3.5 Maximal Aerobic Speed (MAS)

A 1500 m time-trial was used to determine MAS. Participants were grouped into similar abilities within the respective squads for the test. They were instructed to run the 1500 m as fast as possible on an outdoor track and were verbally encouraged throughout. Validity and reliability of this test can be found in Bellenger et al. (2015).

2.4 GPS Analysis

Following training and matches, GPS devices were collected in; the data were then downloaded and analysed using GP Sports software. Only data between August and January was collected and utilised within this study as it represented the start of the season in August up until the final testing bout carried out in January. The U16 squad however did not receive their GPS units until October thus they only have data from October to January. The training data were accumulated from all full-squad training sessions in the mesocycle and divided by the number of sessions during that period, i.e., between August and October or October to January. Within each session, the data includes all activity from start to finish of each session, including rest periods or coaching time. All values displayed in the results are averages of each team in either training or a match. Match values were corrected to 90 minutes for valid comparisons to take place.

Analysis was also carried out based on training category days (i.e. MD -4, -3, -2, -1) as illustrated in table 25. As mentioned previously, the U16 and U18 squads irregularly participate in more than one training session per day, as these were not consistent across mesocycles, nor included the whole squad, they were not included in the training day analysis, and only the principal training session of that training data with the whole squad was utilised to compare with the Reserve squad.

As different GPS devices were used between squads, a GPS validation was planned to be carried out to allow valid comparisons to take place. Due to the pandemic, this validation study was not able to be performed; however, section “2.5 GPS Validation Case Study” below, shows how this study would have been carried out had the pandemic not ceased soccer activities.

2.5 Statistical Analysis

All results are presented as mean ± standard deviation (SD). Upon collation of all testing and GPS data to excel, data were transferred to SPSS software for statistical analysis. Across squad statistical analysis at each timepoint, for both testing and GPS data, was carried out using a one-way ANOVA and Scheffe post-hoc test to determine statistical significance. Testing data were compared in absolute terms, as opposed to relative, to evaluate the actual performance gap between squads (i.e., can an U16 header the ball at the same height as an U18 player if they were head-to-head).

Individual squad analyses of physiological testing data between timepoints was carried out using a Paired T-test to determine statistical significance. Individual squad analyses of GPS data for training and matches between timepoints (i.e., August – October and October – January) was performed using an Independent Samples T-test to determine statistical significance. Levene's equality of variances test was utilised to determine whether equal variances were assumed ($p > 0.05$) or not assumed ($p < 0.05$) to select the relevant p value from the statistical test performed to determine statistical significance. Significance across all tests was accepted at $p < 0.05$.

The physiological testing data in October and January was limited by small sample sizes, therefore partial eta squared was calculated in an ANOVA to determine the meaningfulness of results through indication of effect size (ES). A value of 0.01 indicates a small change, 0.06 a medium change and 0.14 a large change (Cohen, 1973).

3. Results

3.1 October Timepoint Results

3.1.1 October Physiological Testing

Following the start of the season in August, the first battery of physiological testing took place in October. The tests were carried out as described in the methods section for the U16, U18 and Reserve squad. Results of this testing are displayed in the tables below.

Table 5: The mean results for COD, and 30 m sprint results measured using speed gates in October.

		U16	U18	Res
	n	10	9	11
COD (s)	**Left** ^{z}	2.29 ± 0.12	2.21 ± 0.05	2.13 ± 0.06^{a}
	Right ^{z}	2.22 ± 0.12	2.18 ± 0.05	2.12 ± 0.05^{a}
Sprint (s)	**10 m** ^{z}	1.68 ± 0.10	1.64 ± 0.06	1.69 ± 0.04
	20 m ^{y}	2.99 ± 0.18	2.88 ± 0.11	2.93 ± 0.04
	30 m ^{x}	4.21 ± 0.26	4.04 ± 0.14	4.06 ± 0.07
Acceleration (m/s^2)	**10 m** ^{z}	5.96 ± 0.34	6.10 ± 0.24	5.92 ± 0.13
	20 m ^{y}	6.72 ± 0.39	6.94 ± 0.25	6.83 ± 0.10
Speed (m/s)	**Average**	7.15 ± 0.43	7.44 ± 0.26	7.39 ± 0.12
	Maximum ^{y}	8.22 ± 0.55	8.70 ± 0.33^{a}	8.81 ± 0.28^{a}

Note: 'a' significantly different to U16, 'b' significantly different to U18, 'c' significantly different to Reserve squad. Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as 'Mean ± SD'. Effect size was calculated using partial eta squared: '^{x}' indicates a small effect, '^{y}' indicates a medium effect and '^{z}' indicates a large effect.

Change of Direction (COD)

The COD results are displayed in the table above. Evidently, on both sides, COD got progressively faster from U16 to U18 and through to the Reserve squad. The Reserve squad were significantly faster ($p < 0.05$) than the U16 squad by 0.16 s on the left and 0.1 s on the right. Age had a large effect on the results.

30 m Sprint

The sprint results presented in table 5 are varied. The 10 m results highlight the U18 squad as the fastest, followed by the U16 squad then the Reserve squad. Over 20 and 30 m, fastest to slowest followed the order U18, Reserve and U16, though no significant differences were present. In terms of effect size, age had a large effect on 10m results and a medium effect on 20m results.

Acceleration

The 10 m acceleration results from slowest to fastest follow the order: Reserve squad, U16 then U18 squad (table 5). However, the 20 m acceleration order was: U16, Reserve squad and then U18. None of these differences were deemed significant ($p > 0.05$), however a large and medium ES was observed for the 10 m and 20 m accelerations, respectively.

Speed

As shown in table 5, maximum speed is significantly greater ($p < 0.05$) in the Reserve squad and U18s in comparison to the U16 squad by 0.59 m/s and 0.48 m/s, respectively. No significant differences were apparent for average speed over 30 m.

Table 6: All jump results: HJ, SJ, SLJ and VCMJ for the U16, U18 and Reserve squad in October.

		U16	**U18**	**Res**
Horizontal Jump (cm)	**n**	15	14	15
	Bilateral ^{y}	186.48 ± 23.98	203.65 ± 12.77^{a}	198.63 ± 9.44
	n	9	14	15
	Left ^{y}	151.81 ± 17.93	168.14 ± 13.17^{a}	164.97 ± 12.61
	Right ^{z}	147.04 ± 18.47	167.12 ± 11.53^{a}	163.17 ± 11.41^{a}
Squat Jump (cm)	**n** ^{y}	16	13	14
		30.32 ± 3.86	32.05 ± 3.96	34.72 ± 4.41^{a}
Single Leg Jump (cm)	**n**	16	14	15
	Left ^{x}	18.85 ± 2.66	20.03 ± 2.85	19.90 ± 3.13
	Right ^{z}	18.33 ± 3.08	20.25 ± 2.63	20.86 ± 2.21^{a}
Vertical Countermovement Jump (cm)	**n** ^{z}	17	14	15
		32.55 ± 4.97	36.12 ± 3.65	37.61 ± 5.31^{a}

Note: 'a' significantly different to U16, 'b' significantly different to U18, 'c' significantly different to Reserve squad. Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as 'Mean ± SD'. Effect size was calculated using partial eta squared: '^{x}' indicates a small effect, '^{y}' indicates a medium effect and '^{z}' indicates a large effect.

Horizontal Jump (HJ)

Across the bilateral and unilateral HJ results, the U18 squad jumped highest, followed by the Reserves and then the U16 squad. However, no differences were deemed significant.

There is lower participation in the unilateral jump compared to bilateral in the U16 group due to players having difficulty performing the unilateral jump with the correct technique. Hence, the absence of six player's unilateral results. Medium effect sizes were observed in the bilateral and left HJ, a large effect was seen in the right HJ.

Squat Jump (SJ)

The table above displays a progressive improvement in SJ height from the U16 to Reserve squad. The 4.4 cm difference between the U16 and Reserve squad was deemed significant ($p < 0.05$) and had a medium ES.

Single Leg Jump (SLJ)

The table shows the U16s to jump the lowest in both unilateral leg jumps. On the left side, the U18 group jumped the highest, reaching 20.03 cm (1.18 cm higher than the U16 group), though no significant differences were present. On the right side, the Reserve group jumped significantly higher than the U16 group ($p < 0.05$) by 12.13 %, this was also recorded as a large effect.

Vertical Countermovement Jump (VCMJ)

The VCMJ results progressively improve through from the U16 to the Reserve group, as illustrated in table 6. The 5.06 cm difference between the U16 and Reserve group jumps was deemed significant ($p < 0.05$). Age was recorded to have a large effect on VCMJ.

Table 7: The mean force exerted in hamstring strength measurements, both isometrically (Isometric Prone) and eccentrically (Nordic Curl), as well as the MAS for each squad in October.

		U16	U18	Res
	n	17	14	14
Isometric Prone (N)	Bilateral [z]	511.59 ± 136.16	523.64 ± 93.37	591.21 ± 74.06
	Left [y]	244.59 ± 57.68	245.29 ± 54.52	286.14 ± 40.65
	Right [z]	267.59 ± 80.57	278.36 ± 48.95	305.21 ± 38.70
Nordic Curl (N)	Bilateral [y]	614.65 ± 123.53	701.50 ± 119.50	776.36 ± 86.84[a]
	Left [x]	308.71 ± 63.34	349.50 ± 61.96	380.71 ± 41.02[a]
	Right [y]	305.94 ± 63.41	352.00 ± 63.00	395.71 ± 49.49[a]
MAS (m/s)	n [z]	10	8	11
		4.40 ± 0.35	4.75 ± 0.12[a]	4.50 ± 0.26

Note: ‘a’ significantly different to U16, ‘b’ significantly different to U18, ‘c’ significantly different to Reserve squad. MAS:Maximal Aerobic Speed; Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as ‘Mean ± SD’. Effect size was calculated using partial eta squared: ‘x’ indicates a small effect, ‘y’ indicates a medium effect and ‘z’ indicates a large effect.

Isometric Prone

Table 7 shows that across both the bilateral unilateral isometric prone measures, there is a consistent improvement in performance from the U16s to the Reserve squad, though no differences were found to be significant ($p > 0.05$). However, age was recorded to have a large effect on the bilateral results.

Nordic Curl

Nordic Curl results showed also showed a progressive improvement across the age groups. The bilateral results showed a 161.7 N significant increase between the U16 and Reserve squad. Similarly, both unilateral results were significantly greater in the Reserve squad than U16 by 72 N and 89.8 N on left and right sides, respectively ($p < 0.05$). Medium ES was recorded for the bilateral and right Nordic Curl results.

Maximal Aerobic Speed (MAS)

MAS was significantly greater in the U18 squad than the U16s ($p < 0.05$) by 7.37 %, the ES also showed a large effect. The Reserve squad results were less than the U18 results and more than the U16s, though neither difference was deemed significant ($p > 0.05$).

3.1.2 GPS Analysis | August to October

Following the start of the season in August, the training and match data for all squads was collected until the start of October when testing took place. Unfortunately, the U16 squad did not have their own GPS units at this point, thus there is no training or match data for them. The tables below display and compare the training and match variables for the U18 and Reserve team squad.

3.1.2.1 Training Analysis

Table 8: A comparison of mean physical parameters of training between the U18 and Reserve squad for sessions between August and October.

	U18	Res
n	34	34
Duration (mins)	77.90 ± 11.26	79.06 ± 15.14
Distance (m)	4480.69 ± 1074.22	4331.75 ± 1592.68
Dist Per Min (m/min)	57.59 ± 11.09	54.20 ± 13.64
Max Velocity (m/s)	6.74 ± 0.67	7.12 ± 0.83^{b}
Dist >5 m/s (m)	124.66 ± 151.30	183.12 ± 214.82
Dist >7 m/s (m)	12.43 ± 22.81	61.48 ± 96.74^{b}

Note: '^{b}' significantly different to U18. Res: Reserve Squad; U18: U18 Squad. All values displayed as 'Mean ± SD'.

Table 8 shows the U18, and Reserve squad sessions were similar in terms of total distance covered, duration and work-rate (distance per minute) as no significant differences were apparent. However, the Reserve squad reached a significantly higher maximum velocity ($p < 0.05$) by 0.34 m/s. Distance over 7 m/s was significantly greater in the Reserve squad training than U18 training by 49.05 m ($p < 0.05$).

3.1.2.2 Match Analysis

The match data for the U18 and Reserve team squad is displayed below. The data has been corrected to 90 minutes duration to allow valid comparisons between the squads.

Table 9: A comparison of physical demands in matches between the U18 and Reserve squad between August and October.

	U18	Res
n	7	8
Duration (mins)	90.00 ± 0.00	90.00 ± 0.00
Distance (m)	10094.98 ± 370.20	9461.43 ± 595.17[b]
Dist Per Min (m/min)	108.36 ± 5.13	100.55 ± 8.60
Max Velocity (m/s)	8.15 ± 0.20	8.14 ± 0.13
Dist >5 m/s (m)	592.83 ± 52.64	353.60 ± 96.68 [b]
Dist >7 m/s (m)	112.93 ± 28.49	130.27 ± 27.78

Note: ’b’ significantly different to U18. Res: Reserve Squad; U18: U18 Squad. All values displayed as ‘Mean ± SD’.

The U18 squad showed significantly greater distance covered (6.28 %) and distance over 5 m/s (40.36 %) during a match, on average ($p < 0.05$), compared to the Reserves. In contrast to the other parameters, the Reserve squad covered greater distance over 7 m/s by 13.32 %, though not significantly.

3.2 January Timepoint Results

3.2.1 January Physiological Testing

Mid-season, in January, an identical physiological testing battery was carried out, as it took place in October for all three squads: U16, U18 and Reserve squad. Due to limitations, discussed in the limitations section, not all academy testing (i.e., U16 and U18) was completed, resulting in low participation numbers (‘n’) and no MAS results. All obtained results are displayed in the tables below.

Table 10: The mean results for COD and the 30 m sprint for the U16, U18 and Reserve squad, measured using speed gates in January.

		U16	U18	Res
	n	5	7	10
COD (s)	**Left** [z]	2.16 ± 0.06	2.30 ± 0.09[a]	2.16 ± 0.06[b]
	Right [z]	2.14 ± 0.06	2.31 ± 0.07[a]	2.19 ± 0.06[b]
	n	4	3	13
Sprint (s)	**10m** [x]	1.62 ± 0.02	1.63 ± 0.04	1.61 ± 0.05
	20m [z]	2.84 ± 0.04	2.87 ± 0.04	2.81 ± 0.06
	30m [z]	3.99 ± 0.06	4.03 ± 0.05	3.94 ± 0.09
Acceleration (m/s^2)	**10m** [x]	6.17 ± 0.13	6.11 ± 0.07	6.23 ± 0.19
	20m [y]	7.04 ± 0.15	6.96 ± 0.05	7.11 ± 0.16
Speed (m/s)	**Average** [z]	7.51 ± 0.13	7.43 ± 0.07	7.62 ± 0.18
	Maximum [z]	8.17 ± 0.16	8.08 ± 0.03	8.29 ± 0.22

Note: ‘a’ significantly different to U16, ‘b’ significantly different to U18, ‘c’ significantly different to Reserve squad. COD:Change of Direction; Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as ‘Mean ± SD’. Effect size was calculated using partial eta squared: ‘x’ indicates a small effect, ‘y’ indicates a medium effect and ‘z’ indicates a large effect.

COD

The U16 squad significantly faster than the U18 group ($p < 0.05$) with a 0.14 s difference on the left side and a 0.17 s difference on the right. The Reserve group were significantly faster than the U18 group, by 0.14 s and 0.12 s on the left and right sides, respectively. Age had a large effect on results.

30 m Sprint

Table 10 shows the Reserve group to be the quickest across all 10 m splits within the 30 m sprint, followed by the U16 group and then the U18s, no differences were deemed significant ($p > 0.05$). However, ES indicated age had a large effect on results across 20 and 30 m.

Acceleration

Table 10 highlights a progressive increase in 10 m acceleration ability from the U16 group through to the Reserve group, with a difference of 0.09 s, though no differences were noted significant ($p > 0.05$).

Speed

Evident in the table 10, the U18 group showed the fasted maximum and average speed across the 30 m sprint. Though no differences in speed were significant ($p > 0.05$), there was a large ES.

Table 11: Mean lower body power results, obtained from jump testing, across the U16, U18 and Reserve squad in January.

		U16	**U18**	**Res**
Horizontal Jump (cm)	**n**	14	9	15
	Bilateral ^{y}	191.75 ± 22.39	203.54 ± 15.48	207.49 ± 10.50
	Left ^{z}	159.39 ± 18.36	165.94 ± 10.11	177.82 ± 8.70^{a}
	Right ^{y}	158.61 ± 19.53	163.94 ± 10.54	173.10 ± 13.13^{a}
Squat Jump (cm)	**n** ^{z}	13	10	16
		31.45 ± 4.15	33.14 ± 3.20	36.08 ± 4.66^{a}
Single Leg Jump (cm)	**n**	14	10	16
	Left ^{z}	18.83 ± 3.30	19.72 ± 2.81	22.52 ± 2.55^{a}
	Right ^{z}	18.62 ± 2.79	20.58 ± 2.91	22.73 ± 2.88^{a}
Vertical Countermovement Jump (cm)	**n** ^{y}	14	10	16
		35.20 ± 7.16	37.53 ± 4.21	40.08 ± 5.20

Note: ‘^{a}’ significantly different to U16, ‘^{b}’ significantly different to U18, ‘^{c}’ significantly different to Reserve squad. COD:Change of Direction; Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as ‘Mean ± SD’. Effect size was calculated using partial eta squared: ‘^{x}’ indicates a small effect, ‘^{y}’ indicates a medium effect and ‘^{z}’ indicates a large effect.

Horizontal Jump (HJ)

Table 11 presents a progressive improvement in HJ performance from the U16 group through to the Reserve team group. The bilateral jump results showed no significant differences across squads ($p > 0.05$), though there was a medium effect across age groups. The unilateral HJ results showed a significant increase in jump height between the U16 and Reserve squad ($p < 0.05$).

Participation numbers were not an issue between the unilateral and bilateral HJ for the U16 squad in January.

Squat Jump (SJ)

A parallel pattern of results to the HJ is apparent in the SJ, with a progressive improvement in performance from the U16 group to the Reserve team group. The 4.63 cm improvement between the U16 and Reserve group was deemed significant ($p < 0.05$), a large ES was also reported.

Single Leg Jump (SLJ)

The values displayed in table 11 follow the same pattern as the October jumps. The Reserve squad topped the results. On the left side, the Reserve group jumped 2.8 cm and 3.69 cm higher than the U18 and U16 groups, respectively. On the right side, there was a 2.15 cm and 4.11 cm increase from the U18 and U16 groups, respectively. Both the 3.69 cm and 4.11 cm differences between the U16 and Reserve group were deemed significant ($p < 0.05$) and showed large ES.

Vertical Countermovement Jump (VCMJ)

The VCMJ results show jumping height to increase with age of squad as the Reserve squad jumped highest. Though no differences were significant ($p > 0.05$), there was a medium effect.

Table 12: Mean force exerted by hamstring strength, isometrically and eccentrically for all three squads in January.

		U16	U18	Res
Isometric Prone (N)	**n**	13	10	15
	Bilateral ^{z}	601.31 ± 168.11	681.40 ± 127.51	745.67 ± 136.82^{a}
	Left ^{z}	288.38 ± 80.60	327.20 ± 69.49	368.13 ± 77.36^{a}
	Right ^{z}	312.92 ± 91.03	354.20 ± 78.18	377.53 ± 61.76
Nordic Curl (N)	**n**	14	7	15
	Bilateral ^{z}	681.36 ± 102.97	818.14 ± 143.62^{a}	812.73 ± 125.56^{a}
	Left ^{z}	346.71 ± 43.14	400.43 ± 80.15	405.13 ± 70.71
	Right ^{z}	334.64 ± 62.74	417.71 ± 67.27^{a}	407.60 ± 58.27^{a}

Note: $^{‘a’}$ significantly different to U16, $^{‘b’}$ significantly different to U18, $^{‘c’}$ significantly different to Reserve squad. COD:Change of Direction; Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as ‘Mean ± SD’. Effect size was calculated using partial eta squared: $^{‘x’}$ indicates a small effect, $^{‘y’}$ indicates a medium effect and $^{‘z’}$ indicates a large effect.

Isometric Prone

The values displayed in table 12 also illustrate a progressive improvement in isometric hamstring strength from the U16s, to U18s through to the Reserve team group.

The bilateral results highlight a significant 144.36 N improvement from the U16s to Reserve group ($p < 0.05$). The unilateral left results show the same trend with a significant increase ($p < 0.05$) present between the U16 and Reserve team group. Despite the significance on the left-side, no significant differences were found on the right-side. However, there was a large effect over all of the isometric hamstring strength results.

Nordic Curl

The bilateral results show a significant increase in performance from U16 to both U18 and Reserve groups, respectively ($p < 0.05$) with a 16.72 % increase seen in the U18 group and a 16.16 % in the Reserves.

The unilateral left measures show a progressive improvement from the U16s through to the Reserve group, though non-significant ($p > 0.05$). On the right-side, the U16 to U18 difference was 83.07 N (19.89 %) and the U16 to Reserve group difference was 72.96 N (17.9 %) – both of which were significant ($p < 0.05$). However, there was a large effect over all Nordic Curl results.

3.2.2 GPS Analysis | October to January

Prior to October testing, training and match data were collected and compared between squads. This was repeated between the October and January testing, the data for which is displayed below. The U16 squad had received their GPS units, thus they were able to be included in the following comparisons.

3.2.2.1 Training Analysis

Table 13: A comparison of mean physical parameters of training between the U18 and Reserve squad for sessions between October and January.

	U16	U18	Res
n	38	40	44
Duration (mins)	71.76 ± 21.94	71.80 ± 12.20	86.55 ± 14.16 ^{ab}
Distance (m)	4703.31 ± 1463.90	4555.81 ± 981.82	4950.84 ± 1254.92
Dist Per Min (m/min)	66.26 ± 9.91	65.03 ± 13.17	55.22 ± 13.66 ^{ab}
Max Velocity (m/s)	6.60 ± 0.63	6.69 ± 0.50	7.20 ± 0.75 ^{ab}
Dist >5 m/s (m)	120.85 ± 155.28	112.20 ± 134.73	227.83 ± 248.12 ^{ab}
Dist >7 m/s (m)	13.16 ± 34.86	6.34 ± 11.51	50.95 ± 80.34 ^{ab}

Note: 'a' significantly different to U16, 'b' significantly different to U18, 'c' significantly different to Reserve squad. Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as 'Mean ± SD'.

Table 13 displays a significantly greater training duration for the Reserve squad in comparison to the U16 and U18 squads ($p < 0.05$). Though no significant differences were apparent for total distance covered ($p > 0.05$).

Despite the longer duration, distance covered per minute in each Reserve training session was significantly less than both the U16 and U18 training sessions ($p < 0.05$). Though the distance covered over 5 m/s and 7 m/s in their training sessions was found to be significantly greater than the U16 and U18 squads ($p < 0.05$). This pattern is mirrored in the average maximum velocity reached in the training sessions.

3.2.2.2 Match Analysis

Mirroring the match analysis between August and October, all match data were corrected to 90 minutes for each squad to enable comparison of match parameters.

Table 14: A comparison of mean match data between the U16, U18 and Reserve squads, collected between October and January.

	U16	U18	Res
n	8	9	7
Duration (mins)	90.00 ± 0.00	90.00 ± 0.00	90.00 ± 0.00
Distance (m)	9712.77 ± 312.29	10158.77 ± 461.04	9532.50 ± 367.52^{b}
Dist Per Min (m/min)	101.81 ± 5.05	107.59 ± 5.76	99.73 ± 6.65
Max Velocity (m/s)	8.04 ± 0.43	8.02 ± 0.30	8.41 ± 0.25
Dist >5 m/s (m)	607.77 ± 188.35	627.92 ± 97.94	542.57 ± 96.28
Dist >7 m/s (m)	119.00 ± 69.80	109.27 ± 50.21	166.42 ± 52.11

Note: 'a' significantly different to U16, 'b' significantly different to U18, 'c' significantly different to Reserve squad. Res: Reserve Squad; U18: U18 Squad; U16: U16 Squad. All values displayed as 'Mean ± SD'.

The data shows the U18s cover the most distance in a match, then the U16s and finally the Reserve squad, which was significantly less than the U18 squad ($p < 0.05$). The distance per minute results followed the same ranking though no differences were deemed significant.

The Reserve squad reached the highest velocity of the three squads at 8.41 m/s, though this was not significantly faster. No significant differences were reported between squads for distance covered over 5 and 7 m/s, respectively.

3.3 Individual Squad Comparisons

The previous results focus on across squad comparisons, not individual squad differences, showing the results of all participants that were present for testing, whether they had been present for testing in October and/or January. Therefore, the following results examine each individual squad improvements and/or detriments in performance between the October and January physiological testing timepoints, including only players that were present for testing in October and January.

Training and match data analysis between August and January is also presented to support physiological testing findings.

3.3.1 U16 Squad Analysis

The following results focus on the U16 squad physiological testing performance between October and January. Unfortunately, due to no GPS technology being available to this squad prior to October testing, training and match comparisons could not take place. Due to low participation numbers (n=2) in January, no sprint testing results were displayed as they do not represent the U16 squad as a whole. MAS testing was also not carried out in January; hence no MAS comparison was possible.

3.3.1.1 U16 Physiological Testing

Table 15: U16 physiological testing comparisons between October and January.

		October	January			October	January
Horizontal Jump (cm)	**n**	11	11		**n**	13	13
	Bilateral	187.46 ± 25.52	191.64 ± 23.82*				
				Vertical Countermovement Jump (cm)		32.49 ± 5.53	34.40 ± 6.75
	n	9	9				
				Isometric Prone (N)	**Bilateral**	526.08 ± 151.86	601.31 ± 168.11
	Left	151.81 ± 17.93	155.83 ± 17.17		**Left**	249.85 ± 62.92	288.38 ± 80.60
	Right	147.04 ± 18.47	153.11 ± 20.88		**Right**	277.00 90.35	312.92 ± 91.03
Squat Jump (cm)	**n**	12	12	**Nordic Curl (N)**	**n**	14	14
		30.51 ± 3.73	30.92 ± 3.83				
					Bilateral	616.93 ± 132.38	681.36 ± 102.97*
Single Leg Jump (cm)	**n**	13	13		**Left**	309.50 ± 66.60	346.71 ± 43.14*
					Right	307.43 ± 69.08	334.64 ± 62.74*
	Left	19.20 ± 2.81	18.62 ± 3.34				
	Right	18.40 ± 3.41	18.38 ± 2.74				

Note: '' deems significance (p<0.05).*

Evident from table 15, there is a general improvement apparent between October and January. A significant improvement was recorded in the bilateral horizontal jump and in the bilateral and unilateral Nordic Curl. The unilateral HJ results had two less player results than the bilateral due to the technique issues in October testing. The squat jump and VCMJ height improved; the single leg jump results declined, though both differences were non-significant ($p > 0.05$). The NordBord results highlight significant improvements in bilateral and unilateral isometric and eccentric strength ($p < 0.05$).

3.3.2 U18 Squad Analysis

Similar to the U16 squad, October to January testing comparisons were carried out as displayed in the following tables. All data retrieved for players who were present at both testing timepoints is presented. Like the U16, the U18 squad were unable to complete MAS testing, thus was not able to be compared. Weather limitations stopped sprint testing completion resulting in low participation numbers for these tests. The U18 squad had GPS devices across the whole season which allowed training and match comparisons to take place as shown below.

3.3.2.1 U18 Physiological Testing

Table 14: U18 speed testing comparisons between October and January.

		October	January			October	January
COD (s)	**n**	5	5	**Acceleration (m/s^2)**	**n**	3	3
	Left	2.21 ± 0.02	2.32 ± 0.09*		**10 m**	6.24 ± 0.28	6.11 ± 0.07
	Right	2.21 ± 0.04	2.31 ± 0.09*		**20 m**	7.09 ± 0.22	6.96 ± 0.05
Sprint (s)	**n**	3	3	**Speed (m/s)**	**n**	3	3
	10 m	1.61 ± 0.07	1.63 ± 0.03		**Average**	7.61 ± 0.17	7.43 ± 0.07
	20 m	2.82 ± 0.09	2.87 ± 0.04		**Maximum**	8.91 ± 0.13	8.08 ± 0.03
	30 m	3.94 ± 0.09	4.03 ± 0.05				

Note: '' deems significance (p<0.05).*

Between October and January, it seems the players who were present at the October and January testing got slower. The COD test results declined significantly on both sides ($p < 0.05$). All three of the 10 m splits within the 30 m sprint were slower, though not significantly. Resultantly, acceleration, average and maximum speeds all decreased non-significantly in January.

Table 16.1: U18 power and strength testing comparisons between October and January.

		October	January
Horizontal Jump (cm)	**n**	9	9
	Bilateral	207.00 ± 13.44	203.54 ± 15.48*
	n	8	8
	Left	169.59 ± 10.14	167.31 ± 9.88
	Right	168.30 ± 9.86	164.25 ± 11.22
Squat Jump (cm)	**n**	9	9
		33.03 ± 4.24	33.04 ± 3.37
Single Leg Jump (cm)	**n**	10	10
	Left	19.82 ± 2.06	19.72 ± 2.80
	Right	20.04 ± 2.37	20.58 ± 2.90

		October	January
	n	10	10
Vertical Countermovement Jump (cm)		36.86 ± 3.97	37.53 ± 4.21
Isometric Prone (N)	**Bilateral**	548.80 ± 96.58	681.40 ± 127.51*
	Left	260.50 ± 54.56	327.20 ± 69.49*
	Right	288.30 ± 54.10	354.20 ± 78.18*
Nordic Curl (N)	**n**	7	7
	Bilateral	735.29 ± 137.70	818.14 ± 143.62*
	Left	367.71 ± 63.86	400.43 ± 80.15
	Right	367.57 ± 76.35	417.71 ± 67.27*

Note: '' deems significance (p<0.05).*

For the most part the U18 jump performance improved, except the horizontal jump (HJ). The bilateral HJ decreased significantly, whilst the unilateral results decreased non-significantly. The unilateral participation numbers are one player less than bilateral due to a player getting injured whilst performing the unilateral jump. The squat jump and VCMJ improved non-significantly. Isometric hamstring strength (isometric prone) improved significantly with a 132.6 N increase bilaterally and a 66.7 N and 65.9 N increase for the left and right, respectively. Nordic Curl results showed a significant increase in eccentric hamstring strength both bilaterally (82.85 N) and on the right side (50.14 N); there was a 32.71 N improvement on the left side that was not significant.

3.3.2.2 U18 GPS Analysis

As was presented for the across squad analysis, training and match data were collected and examined for the U18 squad to provide further insight into their demands across the season as shown below.

3.3.2.2.1 Training Analysis

Table 17: A comparison of mean U18 training demands between pre-October testing and pre-January testing.

	August - October	October - January
n	34	40
Duration (mins)	77.90 ± 11.26	71.80 ± 12.20*
Distance (m)	4480.69 ± 1074.22	4555.81 ± 981.82
Dist Per Min (m/min)	57.59 ± 11.09	65.03 ± 13.17*
Max Velocity (m/s)	6.74 ± 0.67	6.69 ± 0.50
Dist >5 m/s (m)	124.66 ± 151.30	112.20 ± 134.73
Dist >7 m/s (m)	12.43 ± 22.81	6.34 ± 11.51

Note: '*' deems significance ($p<0.05$).

Table 17 shows a significant decrease in training session duration between October and January in comparison to August to October. Despite the shorter duration, the U18 squad covered slightly more distance, resulting in a significantly greater distance per minute ($p < 0.05$). The distance covered over 5 m/s and 7 m/s showed no significant differences.

3.3.2.2.2 Match Analysis

The match data obtained from GPS devices was corrected to 90 minutes to enable valid comparisons between timepoints for the U18 squad.

Table 18: A comparison of mean U18 match demands between pre-October testing and pre-January testing.

	August - October	October - January
n	7	9
Duration (mins)	90.00 +/- 0.00	90.00 +/- 0.00
Distance (m)	10094.98 +/- 370.20	10158.77 +/- 461.04
Dist Per Min (m/min)	108.36 +/- 5.13	107.59 +/- 5.76
Max Velocity (m/s)	8.15 +/- 0.20	8.02 +/- 0.30
Dist >5 m/s (m)	592.83 +/- 52.64	627.92 +/- 97.94
Dist >7 m/s (m)	112.93 +/- 28.49	109.27 +/- 50.21

Note: '*' deems significance ($p<0.05$).

Generally, match performance was similar between August to October and October to January withno significant differences present. Distance increased by 63.79 m. Maximum velocity decreased slightly by 0.13 m/s. Distance over 5 m/s increased whilst distance over 7 m/s decreased.

3.3.3 Reserve Squad Analysis

Individual squad analysis was also carried out for the Reserve squad to compare physiological testing performance as well as training and match demands. These results are displayed in the following tables.

3.3.3.1 Physiological Testing

Table 19: A comparison of mean Reserve squad speed gate testing data between October and January.

		October	**January**
COD (s)	**n**	4	4
	Left	2.12 ± 0.08	2.14 ± 0.07
	Right	2.12 ± 0.03	2.19 ± 0.05
	n	8	8
Sprint (s)	**10 m**	1.70 ± 0.04	1.60 ± 0.05*
	20 m	2.94 ± 0.05	2.80 ± 0.07*
	30 m	4.08 ± 0.07	3.93 ± 0.10*
Acceleration (m/s²)	**10 m**	5.89 ± 0.13	6.24 ± 0.18*
	20 m	6.81 ± 0.10	7.14 ± 0.18*
Speed (m/s)	**Average**	7.36 ± 0.13	7.64 ± 0.20*
	Maximum	8.78 ± 0.30	8.91 ± 0.33

Note: '*' deems significance ($p<0.05$).

COD

The table above shows only the results of four players who were consistently present at both the October and January tests. Neither COD difference proved to be significant ($p > 0.05$).

30 m Sprint

The results of eight players that were consistent across October and January for sprint testing are shown in the table above. The players got significantly faster across all 10 m splits in the 30 m sprint, with a 3.68 % improvement overall.

Acceleration

Table 19 illustrates the significant improvement in 10 m and 20 m acceleration capacities, by 0.28 m/s^2 over 10 m and 0.33 m/s^2 over 20 m.

Speed

The above table highlights a significant improvement in average speed by 0.28 m/s ($p < 0.05$) and a non-significant improvement in max speed.

Table 20: A comparison of mean Reserve squad power testing data between October and January.

		October	January
Horizontal Jump (cm)	**n**	11	11
	Bilateral	199.41 ± 10.74	204.31 ± 9.79
	Left	165.30 ± 12.45	175.06 ± 7.92*
	Right	162.86 ± 9.92	169.82 ± 13.20
	n	12	12
Squat Jump (cm)		35.10 ± 4.55	35.28 ± 5.00
Single Leg Jump (cm)	**Left**	19.86 ± 3.51	22.09 ± 2.65*
	Right	21.16 ± 2.15	22.11 ± 3.07
Vertical Countermovement Jump (cm)		38.22 ± 5.70	39.27 ± 5.59

Note: '*' deems significance ($p<0.05$).

Horizontal Jump (HJ)

Table 20 shows the only significant result was the significant increase in only the unilateral left jump ($p < 0.05$). The bilateral and unilateral right jumps improved though non-significantly ($p > 0.05$).

Squat Jump (SJ)

As presented above, SJ improved non-significantly ($p > 0.05$).

Single Leg Jump (SLJ)

The values show a significant improvement in the left single leg jump. The right single leg jump also improved, though not significantly.

Vertical Countermovement Jump (VCMJ)

The Reserve squad VCMJ performance improved non-significantly ($p > 0.05$) between October and January.

Table 21: A comparison of mean Reserve squad strength and aerobic capacity testing databetween October and January.

		October	January
	n	10	10
Isometric Prone (N)	**Bilateral**	576.00 ± 68.23	692.10 ± 72.03*
	Left	281.00 ± 39.08	337.00 ± 42.79*
	Right	295.20 ± 33.15	355.10 ± 35.25*
Nordic Curl (N)	**Bilateral**	783.00 ± 84.52	751.70 ± 97.38
	Left	386.50 ± 34.41	372.40 ± 58.59
	Right	396.60 ± 52.15	379.30 ± 43.99
MAS (m/s)	**n**	7	7
		4.46 ± 0.26	4.50 ± 0.22

Note: '*' deems significance ($p<0.05$).

Isometric Prone

Table 21 displays a significant ($p < 0.05$) mean improvement of 116.1 N (16.8 %) in the bilateral measure. There was a 56 N (16.6 %) and a 59.9 N (16.9 %) improvement on the left and right legs, respectively, both of which were deemed significant ($p < 0.05$).

Nordic Curl

The bilateral and unilateral measures decreased on average (non-significantly).

Maximal Aerobic Speed (MAS)

Table 21 reports a non-significant increase in MAS ($p > 0.05$).

3.3.3.2 Reserve GPS Analysis

3.3.3.2.1 Training Analysis

Table 22: A comparison of mean Reserve training demands between pre-October testing and pre-January testing.

	August - October	October - January
n	34	44
Duration (mins)	79.06 ± 15.14	86.55 ± 14.16*
Distance (m)	4331.75 ± 1592.68	4950.84 ± 1254.92
Distance per min (m/min)	54.20 ± 13.65	55.22 ± 13.66
Max Velocity (m/s)	7.12 ± 0.83	7.20 ± 0.75
Dist >5 m/s (m)	183.12 ± 214.82	227.83 ± 248.12
Dist >7 m/s (m)	61.48 ± 96.74	50.95 ± 80.34

Note: '*' deems significance ($p<0.05$).

Table 22 above displays a significant increase in training duration ($p < 0.05$). Distance, distance per minute and maximum velocity all increased between October to January compared to August to October; none of these increases were deemed significant ($p > 0.05$).

The differences in distance over 5 m/s and 7 m/s were significant ($p > 0.05$).

3.3.3.2.2 Match Analysis

Table 23: A comparison of mean Reserve match demands between pre-October testing and pre-January testing.

	August - October	**October - January**
n	8	7
Duration (mins)	90.00 ± 0.00	90.00 ± 0.00
Distance (m)	9461.43 ± 595.17	9532.50 ± 367.52
Distance per Min (m/min)	100.55 ± 8.60	99.73 ± 6.65
Max Velocity (m/s)	8.14 ± 0.13	8.41 ± 0.00
Distance >5 m/s (m)	353.60 ± 96.68	542.57 ± 96.28*
Distance >7 m/s (m)	130.27 ± 27.78	166.42 ± 52.11*

Note: '*' deems significance ($p<0.05$).

The Reserve match data were corrected to 90 minutes, as indicated by the duration in table 23. The data in the table shows differences in distance covered, work- rate (distance per min) and max velocity were non-significant ($p > 0.05$). Distance covered over 5 m/s and 7 m/s both increased significantly ($p < 0.05$), by 188.97 m over 5 m/s and 36.15 m over 7 m/s.

3.4 U16, U18 and Reserve Team Training Category Analysis

As illustrated in table 3 of the methods section, each squad periodises training around match schedules to promote optimal performance on match days. These training days may be MD: -4, -3, -2 or -1, which differ in volume and intensity. The GPS data collected to illustrate the differences is displayed in table 24 below. As previously stated, the U16 squad did not have GPS units until October hence the number of data points is less than the other squads, shown in table 24.

Table 24: Number of data points per squad on each training category day.

	MD -4	MD -3	MD -2	MD -1
U16	8	4	9	6
U18	16	15	14	16
Res	15	13	11	16

As previously stated, the U16 squad did not have GPS units until October hence the number of data points is less than the other squads, shown above in table 24.

Table 25: Differences in training session demands across squads and training days.

		MD -4	MD -3	MD-2	MD-1
Duration (mins)	**U16**	68.11 ± 28.71^{c}	65.22 ± 9.77^{c}	60.01 ± 16.97 ^{bc}	62.09 ± 11.74
	U18	81.84 ± 6.16	83.95 ± 18.02	76.24 ± 11.55	67.21 ± 8.69
	Res	94.27 ± 12.21	90.40 ± 10.41	79.03 ± 15.63	68.63 ± 15.66
Distance (m)	**U16**	4352.03 ± 1970.27	4868.65 ± 580.76	3909.41 ± 1343.00	3637.47 ± 575.13
	U18	4534.06 ± 637.34	5532.84 ± 1447.18	4580.00 ± 557.22	3410.87 ± 494.06
	Res	4636.77 ± 780.70	6375.06 ± 911.23	4225.23 ± 624.76	2903.16 ± 1220.87
Distance per min (m/min)	**U16**	63.04 ± 4.31^{c}	75.00 ± 4.63	65.11 ± 13.45^{c}	59.62 ± 8.09^{c}
	U18	56.16 ± 7.20^{c}	66.10 ± 7.67	60.92 ± 8.46	52.23 ± 7.31^{c}
	Res	49.47 ± 7.01	70.57 ± 7.81	54.04 ± 4.06	40.64 ± 12.43
Distance >5 m/s (m)	**U16**	144.75 ± 159.09	300.36 ± 351.93	43.16 ± 39.25	46.12 ± 12.87
	U18	58.22 ± 41.29	246.80 ± 186.36^{c}	74.06 ± 45.32	45.35 ± 28.23
	Res	81.86 ± 54.15	507.28 ± 242.70	79.06 ± 56.31	37.73 ± 41.61
Distance >7 m/s (m)	**U16**	14.03 ± 19.98	61.55 ± 94.21	1.52 ± 2.18	1.89 ± 2.34
	U18	2.99 ± 6.60	27.27 ± 31.06^{c}	4.52 ± 5.50	1.60 ± 2.26
	Res	12.58 ± 24.35	132.25 ± 112.29	3.88 ± 6.01	2.30 ± 3.96
Maximum Velocity (m/s)	**U16**	6.33 ± 0.66^{c}	7.08 ± 0.57^{c}	6.36 ± 0.46^{c}	6.40 ± 0.24
	U18	6.51 ± 0.45	7.16 ± 0.62^{c}	6.69 ± 0.44	6.37 ± 0.52
	Res	6.95 ± 0.54	7.96 ± 0.42	7.07 ± 0.34	6.35 ± 0.91

Note: 'b' and 'c' deem significance to the U18 and Reserve team squad, respectively ($p<0.05$).

MD -1

The MD -1 data shows that the Reserve squad distance per minute was significantly lower than both the U16 and U18 squad, respectively ($p<0.05$).

MD -2

The MD -2 data shows the U16 squad sessions to be significantly shorter than both the U18 and Reserve team squad. As the U16 squad covered similar distance in training, their distance coverage per minute was significantly greater than the Reserve squad ($p<0.05$). However, the Reserve squad exhibited a significantly greater maximum speed in the MD -2 training sessions.

MD -3

The U16 MD -3 squad sessions were significantly shorter than the Reserve team sessions ($p<0.05$), although their distance covered per minute was similar. The U18 squad covered significantly less distance than the Reserve squad over both 5 m/s and 7 m/s, respectively ($p<0.05$). Additionally, both the U16 and U18 squad attained significantly lower maximum velocities than the Reserve squad in MD -3 sessions ($p<0.05$).

MD -4

The data produced for MD -4 sessions shows significantly shorter duration in U16 sessions compared with the Reserve squad, however the U16 squad distance covered per minute was significantly greater than the Reserve squad ($p<0.05$) as they covered similar total distance.

3.5 Reserve Team vs First Team Analysis

Comparison of Reserve and First Team training and match demands was carried out to examine the differences as players progress to top professional level. The following analysis includes training sessions and matches across the season.

3.5.1 Training Analysis

Table 26: A comparison of mean training demands between the Reserve and First Team across the season.

	Res	1st
n	78	71
Duration (mins)	83.29 ± 14.97	69.98 ± 23.52*
Distance (m)	4680.98 ± 1435.98	3804.29 ± 2111.30*
Distance per minute (m/min)	55.91 ± 13.65	52.48 ± 18.97
Max Velocity (m/s)	7.17 ± 0.78	6.57 ± 0.96*
Distance >5 m/s (m)	208.34 ± 233.79	103.03 ± 175.89*
Distance >7 m/s (m)	55.54 ± 87.43	19.11 ± 53.89*

Note: '' deems significance (p<0.05).*

The data in the table above shows the duration of training sessions were significantly shorter ($p < 0.05$) in the First Team than the Reserve squad by 16 %. The Reserve squad showed significantly greater ($p < 0.05$): distance covered (18.3 %), maximum velocity reached (8.38 %) and distance over 5 m/s (49.45 %) and 7 m/s (65.6 %) respectively.

3.5.1.1 *Training Category Analysis*

Each squad periodises training around match schedules to promote optimal performance on match days. These training days may be MD: -4, -3, -2 or -1, all of which differ in volume and intensity. The table below includes all categorised training days regardless of First Team match prevalence as the content of each periodised training session remains consistent.

Table 27: A comparison of mean training category data between the Reserve and First Team squad.

		Duration (mins)		Distance (m)		Distance per min (m/min)		Max Velocity (m/s)		Distance >5 m/s (m)		Distance >7 m/s (m)	
		Res	**1st**	**Res**	**1st**	**Res**	**1st**	**Res**	**1st**	**Res**	**1st**	**Res**	**1st**
MD -1	**n**	16	26	16	26	16	26	16	26	16	26	16	26
	Mean ± SD	68.63 ± 15.66	72.61 ± 19.00	2903.16 ± 1220.87	2681.62 ± 653.23	40.64 ± 12.43	37.50 ± 6.36	6.35 ± 0.91	6.34 ± 0.50	37.73 ± 41.61	26.05 ± 21.98	2.30 ± 3.96	2.00 ± 2.54
MD -2	**n**	11	12	11	12	11	12	11	12	11	12	11	12
	Mean ± SD	79.03 ± 15.63	80.25 ± 9.61	4225.23 ± 624.76	5257.04 ± 568.43*	54.04 ± 4.06	65.75 ± 4.62*	7.07 ± 0.34	6.94 ± 0.30	79.06 ± 56.31	76.31 ± 50.28	3.88 ± 6.01	5.66 ± 5.73
MD -3	**n**	13	10	13	10	13	10	13	10	13	10	13	10
	Mean ± SD	90.40 ± 10.41	99.26 ± 20.20	6375.06 ± 911.23	7340.08 ± 922.81*	70.57 ± 7.81	75.64 ± 11.62	7.96 ± 0.42	8.07 ± 0.68	507.28 ± 242.70	420.12 ± 272.56	132.25 ± 112.29	107.28 ± 108.71
MD -4	**n**	15	6	15	6	15	6	15	6	15	6	15	6
	Mean ± SD	94.27 ± 12.21	74.71 ± 13.54*	4636.76 ± 780.70	5313.22 ± 920.69	49.47 ± 7.01	71.49 ± 6.96*	6.95 ± 0.54	7.02 ± 0.63	81.86 ± 54.15	165.70 ± 141.14	12.58 ± 24.35	20.07 ± 27.13

Note: '' deems significance (p<0.05).*

MD -1

The data displayed for MD -1 shows no significant differences between the Reserve and First Team sessions. The Reserve sessions were almost four minutes shorter, on average, than the First Team. However, the Reserve distance, distance per minute, max velocity, distance over 5 m/s and 7 m/s were all greater.

MD -2

In contrast to MD -1, the First Team typically cover significantly more distance (19.6 %) at a higher work-rate (distance per min) (17.8 %) than the Reserve squad in MD -2 sessions ($p < 0.05$). Other differences displayed were non-significant ($p > 0.05$).

MD -3

The First Team covered significantly more distance (almost 1 km) than the Reserve squad ($p < 0.05$) at a higher work-rate (approximately 5 m more per minute), though not significantly ($p > 0.05$). Differences in max velocity and high-speed distance > 5 m/s and 7 m/s, respectively were non-significant.

MD -4

The data produced for MD -4 sessions presents interesting findings. Despite a significantly longer session duration ($p < 0.05$), the Reserve squad covered roughly 13 % less distance per session. Consequently, the Reserve work-rate (distance per min) was significantly less than the First Team sessions by 22.02 m per minute. Maximum velocity and distance over both 5 m/s and 7 m/s were greater in the First Team sessions, though not significantly.

3.5.2 Match Analysis

As was carried out for the younger squad comparisons, the Reserve and First Team match data were corrected to 90 minutes for comparison.

Table 28: A comparison of mean match demands between the Reserve and First Team across the season.

	Res	1st
n	16	20
Duration (mins)	90.00 +/- 0.00	90.00 +/- 0.00
Distance (m)	9494.54 +/- 481.54	10062.06 +/- 260.90*
Distance per minute (m/min)	100.14 +/- 7.43	106.63 +/- 4.02*
Max Velocity (m/s)	8.28 +/- 0.24	8.46 +/- 0.14*
Distance >5 m/s (m)	448.08 +/- 134.94	190.65 +/- 35.16*
Distance >7 m/s (m)	148.34 +/- 44.45	19.06 +/- 7.80*

Note: '' deems significance (p<0.05).*

First Team match data shows significantly greater (p <0.05) distance covered (5.65 %), distance per minute (6.1 %) and maximum velocity reached (2.13 %). However, the Reserve squad covered significantly more high-speed distance: 135 % and 678 % more over 5 m/s and 7 m/s, respectively.

4. Discussion

4.1 Summary Statement

Transitioning academy players to First Team level is vital for a club's financial survival. Previous literature has examined physical capacities and match performance in youth soccer, primarily across U13 to U18 age groups (Buchheit et al., 2010). However, no literature that the author is aware of has investigated the transition from youth to professional level from top academy age groups (i.e., U16 and U18), through the transitional Reserve team squad, and into top tier professional soccer.

The findings of this study generally showed the Reserve squad to be the most physiologically superior compared to the academy squads. Training and match results were not entirely as hypothesized: in some instances, the U18 and U16 squads surpassed the Reserve team squad. Furthermore, the average First Team training content was significantly less than the Reserve squads, though their match performance was significantly superior. These points are examined in greater depth in the following discussion.

Due to the Coronavirus pandemic, not all testing was completed thus only October and January testing results were able to be compared. Other limitations also meant January testing was not completed in the academy, as discussed in the limitations section.

4.2 Physiological Testing and GPS Analysis

One of the aims of this study was to determine whether physical capacities differed between age groups across a single season. It was hypothesised that physical capacities would improve with age and level of play as physical prowess is known to increase with growth (Papaiakovou et al., 2009; Philippaerts et al., 2006).

As a multi-faceted sport, soccer requires many physiological qualities to compete at a high level, including: agility, speed, power, strength and endurance. These qualities were investigated in this study using various testing measures in both October and January.

4.2.1 Speed and Power

Speed

Buchheit et al. (2010) examined the physical profiles of youth soccer players from U13 to U18 level. They reported a progressive increase in peak velocity with age in a 40 m sprint test. The October findings of this study coincide with Buchheit et al. (2010) as peak velocity was significantly greater in the U18 and Reserve team groups compared to the U16, with the Reserve group achieving the highest peak velocity (table 5). However, the U18 squad covered the 30 m distance marginally (0.02 s) faster than the Reserve squad. It was unusual that the Reserve squad reached the highest peak velocity yet, did not cover the 30 m the fastest. This can be explained by the 10 m split results. Evidently, the U18 squad accelerated the fastest over 10 and 20 m; however, the Reserve squad covered the 20 – 30 m split the fastest, where they achieved peak speed. Whilst these differences are unusual, it is important to remember that these results are averages, and only a minute proportion of players will succeed to the top level (Calvin, 2017). Therefore, looking at results on an individual, as well as a team, basis is crucial for talent identification.

Low participation numbers in January sprint testing limit the conclusions that can be drawn from table 10. The ES calculated, suggested age has a small effect on 10 m speed and a large effect on 20 and 30 m sprint-splits, respectively. However, the ES data are limited across all testing as the partial eta-squared was calculated across all three squads and not between the U16 and U18, U16 and Reserve, or U18 and Reserve squads, respectively, thus does not state where the effect has occurred specifically. Regardless of statistical tests selected to determine meaningfulness of results, the low participation numbers are not a representation of the respective U16 and U18 squads. Though the four U16 squad players present performed marginally better than the three U18 squad players. This snapshot indicates that some U16 players may be physically robust enough to progress and withstand the demands at U18 level, further emphasising the need to examine progression on an individual, as well as a team, basis.

Another limitation of this study was testing days varied between squads in addition to days to and from a match, therefore fatigue levels inevitably differed and may have affected results. However, the large ES calculated across sprint performance indicates that age group, or level of play, has a large effect on sprint performance, as the Reserve squad topped sprint performance across all parameters. The October to January training data in table 13 suggests the significantly greater distance covered in training over 5 m/s and 7 m/s, respectively, may explain this Reserve squad superiority in January; though the same trend was not the observed in matches. As each squad only competes in one match per week, this is unlikely to be as impactful on performance as regular training sessions. This greater and more regular exposure to high-speed distance may have assisted Reserve squad linear speed gains through development of faster running biomechanics and NM activation. Additionally, the regular targeted S+C sessions, focusing on speed, strength and power likely had a positive effect on their performance. The enhancement of these physical qualities increases ground reaction forces, whilst reducing ground contact time, therefore increasing sprint performance (Wild et al., 2011).

The October COD results in table 5 indicate the Reserve squad to have a greater COD ability, although the U18 group accelerated faster over 10 and 20 m and covered the 30 m distance slightly quicker. Given the average sprint distance in a match is 18-20 m (Di Salvo et al., 2010) the U18s would edge the advantage in a head-to-head situation, however, this may only be the case if the head-to-head is in a straight line, as the Reserve squad exhibited faster COD results. The tenths of a second differences between squads are not very meaningful in a match situation, it is likely the outcome of possession in a head-to-head, whether in a straight-line or at an angle, would be decided by technical execution and tactical intelligence.

Despite the uncertainty of academy sprint results in January, the jump results may provide a better insight into their physical capacities.

Power

Sprint speed and vertical jump performance are known to strongly correlate due to similar motor unit recruitment patterns and reliance on strength to produce force (Comfort et al., 2014). Thus, jump measures were included alongside sprint performance. Both sprint and jump ability are key to match performance to gain advantage over the opposition. Barnes et al. (2014) reviewed the evolution of the soccer game between 2006 and 2013; over the 7 seasons they found a far greater high-intensity running distance, sprint distance and number of sprints – particularly short, explosive sprints in the latter years. These findings emphasise the importance of sprint and power development in youth soccer and suggest a strong speed and power profile will assist in progression to the next level.

Working at higher speeds requires greater neuromuscular (NM) activation (Ross, Leveritt and Riek, 2001) which assists power generation, and therefore jumping ability, as shown by the Reserve's vertical jump results in October (table 6). January power results, displayed in table 11, are consistent with October as the Reserve squad proved superior. The ES also indicated that age had either a moderate or large effect on results across all jump results.

The most notable jumping movement in soccer is heading the ball, which Hughes (1990) reported to account for one in every five goals scored. Analysis carried out in English League 2 in 2013 suggests that this statistic still stands in modern soccer as 21 % of goals were scored with a header, 46 % from open play and 54 % from set-plays (Football Performance Analysis, 2013). Headers from open play are likely to require a one-footed take-off on the move, whereas headers scored from set-plays may allow a two-footed take- off. This highlights the requirement for elite soccer players to possess both unilateral and bilateral jumping ability. The jump testing was more controlled than the sprint testing as all jumps were recorded indoors on the same force plates. It is evident that the Reserve squad have a greater bilateral jumping ability thus may give them the advantage in chances in a head-to-head heading opportunity with other squads. The author acknowledges height and mass differences shown in table 2 when discussing the jump results, however, a player moving from one squad to another must be able to match the qualities of players at the next level in absolute terms to have a chance of competing at that level.

Vertical power is commonly measured using the simple and reliable VCMJ (Dias et al. 2011). The Reserve squad exhibited the greatest vertical power in October, significantly more so than the U16 group (see table 6). All lower limb power results in January also followed the order (best to worst): Reserve, U18 and then U16 (see table 11). This again shows the progressive improvement from U16 through to the Reserve team. As the sprint times decreased from the U16 to the Reserve squad, the jump heights increased.

It seems evident that a greater leap in ability exists between the U16 and U18 squad than between the U18 and Reserve team groups. The burning question remains: why is this?

Unfortunately, the U16 team did not have GPS units prior to October testing, making it difficult to determine whether training or match intensity contributed to the lesser results. Despite this, it may be possible that maturation has influenced their speed and power capacities (Lloyd and Oliver, 2014). While all players in this study had surpassed peak maturation, it is still important to acknowledge the knock-on effects that maturation may have posed on performance.

Maturation encompasses significant development of both the skeletal and endocrinological systems within the body. During these periods of rapid growth, overuse injuries are common making it important for coaches to periodise training accordingly (Hutchinson and Nasser, 2000). This rapid growth phase is known as peak height velocity (PHV) which occurs at around 14 years of age in males (Stratton et al., 2004) with an average growth spurt of 8.3 cm (Growth Charts, 2001). The increase in stature is accompanied by a decline in motor skills as the individual must re-calibrate their coordination systems to perform these skills effectively (Beunen and Malina, 1988). Following this phase, many hormones increase within the body, namely testosterone and the growth hormone, which respond positively to strength training and plyometrics, encouraging neural development and muscle hypertrophy (Rumpf et al., 2012). Pearson, Naughton and Torode (2006) reported anaerobic power capacities to increase by approximately 50 % during puberty; the same paper also stated an approximate increase in strength of 150 % during the same period. This may be explained by Hansen et al. (1999) who illustrated strength development to be significantly related to increases in serum testosterone changes in youth male soccer players. Power and speed are related due to their mirroring motor unit recruitment patterns and strength requirements to produce force. Therefore, it makes sense that the U18 and Reserve squads exhibited significantly greater power scores to the U16 age group. The older squads have been exposed to more hypertrophic strength training following maturation and thus have had a greater window of opportunity to develop force generation capacities.

Training must vary between age groups to be coherent with the dose-response relationship and General Adaptation Syndrome (GAS) (Selye, 1956). The dose-response relationship is applied in relation to training experience and athletic status. Therefore, by adapting frequency, intensity and volume, sessions can be tailored to each age group appropriately. This also means that the Reserve squad can train with a greater ‘dose’ as they have the most training experience. The GAS generically describes a physical response to a stress and is characterised by three phases: 1. initial shock to stressor, 2. supercompensation – the body acts to increase capacities necessary to cope with the stressor. The third phase highlights danger associated with stressor overexposure which may lead to maladaptation (Brown and Greenwood, 2005). This highlights the need for tailored training to each respective squad as well as training variation and periodisation to prevent injury and maximise performance.

NM activation evidently is key to physical performance. In pre-adolescents, movement patterns are practiced to build a strong NM base to work from following maturation. Taking the dose-response relationship and GAS into consideration, NM activation and strength training are executed differently between age groups. The U16 strength training had only started this season, using primarily bodyweight exercises to build a strong base to work from in future. The latter age groups were put under greater stress by using free weights which require postural control and intermuscular coordination (Bryanton and Bilodeau, 2018). With respect to NM progression, it is thought that increasing stability and mobility of each session and training frequently will produce the greatest improvements (as opposed to increasing repetitions and resistance) (Carroll, Riek and Carson, 2001). The U16 group undertook two strength sessions per week, in comparison to three in the U18 group and four in the Reserve squad. Resultantly, the more frequent strength sessions targeting NM activation favoured the latter squads power testing results and Reserve sprint performance in October and January.

Differences between the U18 and Reserve squad were not significant across any speed or power measures, thus the U18 would likely be able to compete in terms of speed and power.

Strength is key to soccer success, though stronger isn’t always better. Fundamentally, a player must be able to transfer their gym-strength into skill execution and movements on the pitch, otherwise their newfound strength is not benefitting performance. Coaches have often reported that their best players are not always the players that can lift the most weight in the gym (McGill, 2006). The transition of training effects to match-play is crucial to progress towards top tier soccer. This being said, the importance of strength cannot be overlooked. In contrast to NM activation, strength gains are influenced by intensity, frequency and volume of sessions (Baechle and Earle, 2000). Rhea et al. (2003) reported the need to increase the ‘dose’, i.e., intensity, volume and frequency, as the NM system develops and becomes more adapted to strength training to continue to elicit a response. The greater training experience of older squads enables them to be exposed to a greater ‘dose’ of strength training which has likely had an impact on the sprint and power results.

Physical preparation for the next stage is not always making sure a squad can physically match the squad above, as they often cannot safely perform at the same workload. The ultimate goal is progression. When an U16 player progresses to U18, it is important that they have solid foundations to work and improve from, both on the pitch and in the gym, to progress towards working at that squad’s workload.

4.2.2 Strength

Despite not measuring lower limb strength by the common means of a 1RM-squat test, this study directly measured hamstring strength using novel technology. It is in both the player’s and club’s interest to measure eccentric capacity to reduce hamstring injury prevalence and the economic burden of injury.

Non-contact soft-tissue injuries are arguably one of the most frustrating for a player and club as they are largely preventable through load management (Gabbett, 2016). Due to soccer’s eccentric nature, hamstring injuries are the most common to plague soccer players. In the 2016/17 season, the English Premier League (EPL) reported 150 hamstring injuries, resulting in 4165 days of training and matches being missed (Physioroom.com, 2017). The return to play timeframe varies from injury to injury: returning too quickly can result in a subsequent injury and cost clubs' expensive wages while the athlete cannot compete. The same source reported the EPL total injury wage bill to exceed £180 million. This monumental, partially avoidable, expenditure can be reduced by managing risk factors.

McCall et al. (2014) ranked 5 risk factors of non-contact injuries from most important to least important: previous injury, fatigue, muscular imbalance, fitness and movement efficiency. Four of the five factors are manageable. As a player progresses from youth to professional level it is particularly important to monitor and manage fatigue. Fatigue inevitably increases with match congestion, subsequently increasing injury prevalence (Bengstsson, Ekstrand and Hagglund, 2013). Therefore, as a player transitions from playing one to up to three matches per week, it is important to ensure their overall fitness and physical robustness can cope with the heightened physical demands.

In recent years isometric and eccentric hamstring strength have been able to be measured directly. This study measured eccentric strength with a Nordic Curl and isometric strength with the isometric prone, the results for October and January are displayed in tables 7 and 12. Both hamstring strength measures were greatest in the Reserve squad and lowest in the U16 squad. The Reserve and U18 squads performed significantly better than the U16 squad in bilateral and unilateral-right measures in January. This may suggest a greater hamstring injury risk in the U16 squad; however, injury prevalence was not recorded. The hormone levels following maturation, discussed previously, that promote muscle growth and strength gains likely influenced these results; the U18 and Reserve squad have had a greater timeframe to develop strength within a gym setting. Additionally, the Reserve squad are based at the same training ground as the First Team thus have daily access to all the top equipment. This may have aided Reserve squad strength development. As this testing had just been introduced this season, the older squads did not have a familiarity advantage.

Despite no statistical significance, the U16 and U18 are performing at 80 % and 90 % of the Reserve squad eccentric capacity, respectively in October (table 7). To minimise injury risk for transitioning players, it may be suggested to incorporate Nordic Curl exercises into a prehab program. By adopting a proactive rather than reactive approach to strengthening hamstring muscles, future training and match absence could be minimised. Peterson et al. (2011) implemented a Nordic Curl eccentric strength program intervention in 461 soccer players which reduced new injuries by 60 % and recurrent injuries by 85 %.

The U16 age group results highlighted that their speed capacities may be more developed than their eccentric strength. Given that this squad have only recently commenced their strength program, this was not unexpected: their exposure to speed training and sprinting has been far greater than eccentric strength training thus far, as they have only commenced their strength program. Perhaps towards the end of the season the sprint and strength capabilities would be more balanced, as they would have undertaken more eccentric strength training by then. This was unable to be measured due to the Coronavirus pandemic.

Strengthening hamstrings and reducing injury risk by this much would assist a player to withstand the increased eccentric demands of the next level of play and increase chances of success.

4.2.3 Aerobic Capacity

In addition to reducing injury risk, fitness is essential to maintain a high-intensity of play throughout the entirety of a 90-minute match. The intermittent nature of soccer requires developed aerobic and anaerobic systems for successful performance. Ekblom (1986) recognised aerobic capacity as a fundamental factor to match success as it influences several key aspects of match performance, including: distance covered, number of sprints, time spent in higher speed zones and touches of the ball (Helgerud et al., 2001). A heightened aerobic capacity accelerates an individual's recovery time between sprints, subsequently improving repeated sprint ability (RSA). Literature states higher intensity work to be the distinguishing factor between elite and lower levels of play, as elite players typically cover 2 – 3 km more distance over 15 km/h and 0.6 km over 20 km/h (Iaia, Ermanno and Bangsbo, 2009), therefore as a player becomes more elite, their ability to perform high-intensity intermittent activity must improve in parallel. However, the other 80 – 90 % of the match consists of low to medium intensity activities (Bangsbo, 1994, 1997; Rienzi et al., 2000).

Using a 1500 m TT, each squad's maximal aerobic speed (MAS) was determined (see table 7). Due to limitations, MAS testing was only completed across all squads in October, not January. It was expected that MAS would increase with age; however, the U18 squad exhibited the best MAS which was significantly greater than the U16 squad. No GPS data is available for the U16 squad prior to October testing, making it difficult to determine why the U16 squad had a significantly lesser aerobic capacity; match intensity may be presumed to be lower for this squad as well as the requirement for repeated intermittent sprints. Looking at table 14, the differences in high-intensity distance in matches are non-significant between squads, therefore the lack of high-intensity reported in lower-level matches in literature may not be the case in this instance. The data were collected between the October and January testing so is limited in that it is not directly related to the October MAS testing, yet it gives an indication of the typical match intensity experienced by each respective squad. Further limitations exist as the values in this table are averages of distances covered across multiple

90-minute matches and do not take the number of sprints, time between sprints and other sprint characteristics that may have provided better insight into the MAS results. This should be an area of future research.

Although the majority of studies in soccer have utilised the YoYo running test to assess aerobic capacity, they are testing the same physical attribute. The YoYo is often chosen as it mirrors the intermittent nature of a match. Teplan et al. (2012) reported U17 players to possess a greater intermittent running capacity than U16 players. The findings of this study are in concord with those of Teplan et a., (2012) as the U16 group showed the lowest aerobic capacity. Strøyer, Hansen and Klausen (2004) found match load intensity to increase in young players with age, which Teplan et al. (2012) acknowledged as a determining factor of aerobic capacity. Although the First Team did not perform the 1500 m TT in this study, it may be hypothesised that their results would have been superior to the U16, U18 and Reserve squads as studies have shown aerobic capacity, or high-intensity intermittent running capacity, to increase with level of play in adult players (Mohr, Krustrup and Bangsbo, 2003; Krustrup et al., 2003; Castagna et al., 2006).

The MAS results of this study may be slightly flawed as Bellenger et al. (2015) stated the 2000 m TT to be the most accurate at measuring MAS. They found that TT distances less than 2000 m over-predicted MAS, while TT distances over 2000 m under-predicted MAS. Therefore, the results displayed in table 7 likely over-predict the true MAS scores of the squads in this study. Despite this, as all squads performed the same TT, the scores can still be compared with each other to show where each squad lies in terms of each other. It may be recommended to test MAS using a 2000 m TT in future. Furthermore, perhaps a YoYo test could be carried out in future; many studies select this method as it more accurately mirrors the intermittent nature of soccer.

4.2.4 GPS Analysis

Physical testing is a great way to assess the physical capacities of players throughout a club. However, without the ability to transfer these qualities into training and match-play, a player will not succeed to the next professional tier. As the physical stresses increase with level of play, it is important to ensure players are being exposed, but not over-exposed, to these increasing demands. The training and match data in tables 8, 9, 13 and 14 enable evaluation of this.

Aside from supporting testing results, the GPS data highlighted discrepancies between training and match data for the Reserve squad but more so the U18 squad (see tables 8 and 9). It is commonly stated in literature that the deciphering factor between levels of play in soccer is the distance covered in higher speed zones in matches (Mohr, Krustrup and Bangsbo, 2003). The significantly greater distance covered in higher speed zones by the Reserve group than the U18 team in training concords with the literature. Looking at the training data alone raises concern as it suggests that the younger U18 squad may not be capable of reaching and sustaining higher speeds. However, the match data in table 9 proves that this is not the case. The U18 squad cover significantly more distance over 5 m/s than the Reserve squad, a monumental 4.75 times what they cover in their average training day. Although they cover slightly less distance over 7 m/s than the Reserve squad, they cover over 9 times the distance they do in training. Of course, tactics inevitably vary with different opposition and uncontrollable factors such as the playing conditions: these will ultimately determine the physical match demands (Rein and Memmert, 2016). Although this will have altered the outputs of the teams in table 9, this is something that must be considered as a player progresses to the next level. The U16 team may have played more defensive tactics throughout the season, as opposed to more attacking tactics in the U18 squad. This highlights the requirement for a player to be able to adapt and respond to changes in opposition and tactics from match-to-match. The teams at Celtic were typically attacking in nature throughout the season as they were in the top rankings of their respective leagues. The tactical differences were not addressed when examining match data as they changed match-to-match depending on the factors mentioned above – the average values displayed in table 9 provide an insight into the physical demands players these squads experience in gameplay at their level.

For example, the data in table 14 illustrates that the Reserve squad covered the least total distance of the three squads, yet reached a higher maximum velocity and covered greater distance over 7 m/s. Match results are influenced by uncontrollable factors: the Reserve squad may have attained more distance over 7 m/s and reach the highest maximum velocity as they had more opportunity in the game to open up and accelerate into space than the other squads. The same goes for the academy squads covering greater distance over 5 m/s, their opposition may have allowed them more space to move into, though perhaps not as much as the Reserve squad to fully open up over 7 m/s. It is possible that the Reserve squad did not need to cover more distance to maintain possession and dominance in their matches. Match results have not been reported in this study as they do not always convey a true representation of the game: goals can be scored from fast-breaks and counterattacks thus results often don't mirror possession. Furthermore, tactical differences subject squads to different demands (Baptista et al., 2019). For example, if the Reserve squad adopt defensive tactics and sit back on the pitch to defend their goal, they are likely to cover less distance. On the contrary, attacking tactics would permit more forward, fast-paced movement on the pitch towards the opposition goal, heightening the relevant GPS parameters.

The aim of training is to prepare players for these match demands. The data across tables 8, 9, 13 and 14 at surface level may imply that squads are not being adequately prepared for matches in training, augmenting non-contact soft-tissue injury risk (Gabbett, 2016). However, periodisation of training must be considered. Table 3 shows the typical week schedules for the U16, U18 and Reserve squads, highlighting only one match day per week for all squads. As gameday approaches training load is manipulated to optimise competitive performance (Reilly, 2005). In addition to optimising competitive performance, managing training load through periodization may positively impact fitness levels and reduce injury occurrence. Table 3 displays the harmonious lead-in to matches across squads. The average physical output of these sessions is displayed in table 25. Evidently, the most intense session in the training week is MD -3, with the greatest total distance and distance in high-intensity speed zones being covered on that day. The Reserve squad also typically covered more distance in these higher speed zones, on average, than the younger squads; this is likely to assist them in their preparation for more demanding match play that literature refers to (Mohr, Krustrup and Bangsbo, 2003). The most consistent finding in table 25 is that the U16 squad have a shorter, more intense (in terms of distance per minute) training sessions than the U18 and Reserve squads. Furthermore, the U16 total distance covered in sessions does not seem to vary to the same extent as the other squads. This may be to expose them to a higher chronic workload and enhance physical robustness. Bowen et al. (2017) studied the acute:chronic workload ratio in elite youth soccer players and concluded that a gradually increasing chronic workload will enhance tolerance to higher workloads and resilience to injury risk, thus this may assist the U16 group as they progress to competition at U18 level. However, a balancing act remains to find the optimum training stimuli to initiate a positive response, in coherence with Selye's General Adaptation Syndrome. When the acute and chronic loads are too similar, injury risk is increased (Bowen et al., 2017).

To enable further comparison, the average accumulated workload for each squad was calculated, based on the values in table 25, as below:

Table 29: The weekly physical demands that the U16, U18 and Reserve squad experience.

	Total Duration (mins)	Total Distance (km)	Average Distance per min (m/min)	Average Max Velocity (m/s)	Total Distance >5 m/s (m)	Total Distance >7 m/s (m)
U16	345.43	26.71	73.50	6.85	1168.69	208.86
U18	399.24	28.19	68.67	6.96	1036.99	147.26
Res	422.33	27.63	62.97	7.32	1154.02	299.35

The Reserve team sessions were longer in duration than the other squads resulting in a lower distance per minute, which may have been a result of extra coaching time. The training data are an average of all activities between the start and end of a session, including rest periods, therefore is not an exact representation of the squad demands. To improve this in future, only the GPS data for each training exercise could be included to understand the session design for each squad in more depth and therefore, the demands. In addition, the irregularity of the U16 and U18 microcycles were addressed in the methods section: some players within these squads undertake additional pitch sessions on different days and at different times to improve weaknesses or partake in extra fitness work. This is not consistent across microcycles, nor includes the majority of the squad, therefore only the main training session for each training category day was included. Resultantly, the U16 and U18 data displayed are not the exact demands that all players in the respective squad's face. Ultimately the accumulated load across each squad's typical microcycle is similar, however the individualisation of training seen in the U16 and U18 squads may suggest that an individual monitoring approach may be necessary for younger squads and a team-oriented monitoring approach for more senior squads.

Despite the limitations of the GPS match data across the season, these findings indicate that the younger squads could withstand the physical demands of a Reserve team match. The question then turns to whether the younger players have the technical proficiency, tactical knowledge and game awareness to outplay a more experienced opposition. These skills will naturally improve with playing experience and are likely to be the deciding factor on whether a player with strong physical foundations is ready to progress to a more elite level.

4.3 Individual Team Progression

The October and January testing results give a good overview of where each team lies in terms of each other, however all players were included in these analyses, regardless of consistent attendance in both October and January.

Therefore, the natural step was to examine the individual team results including only players that were present in both October and January. The following sections examine this more refined analysis for the U16, U18 and Reserve squads, respectively.

4.3.1 U16 Squad Analysis

Of the comparable tests between October and January for the U16 squad, five of the six tests displayed an improvement. Unfortunately, due to limitations with weather and coaches (discussed in the limitations section) MAS testing was not completed and only two players were present for both sprint tests. Thus, only the jump and hamstring testing data were available for valid comparison. Due to this squad not having GPS prior to October testing, training and match comparisons were not possible, nor were they able to support physical testing findings across the season.

Following the October testing, general squad strength and weaknesses were identified. Given that this squad were new to S+C, rather than individualizing areas of improvement, a general program was designed to encourage general athlete development and build a solid strength foundation to work from as their physical capacities improve.

From the results displayed in table 15 it is evident that lower limb power improved between October and January. As discussed previously, the U16 had only begun gym work this season to improve speed, strength and power, amongst other physical qualities. Having recently passed their PHV, gym sessions were introduced gradually, doing two bodyweight resistance and plyometric sessions per week. Due to maturation effects, it would be inappropriate to introduce strength sessions with weights, hence the introduction of bodyweight resistance and plyometrics.

Plyometric exercises, such as box jumps, are ideal for developing youth players to stimulate and improve their NM systems using the stretch-shortening cycle (SSC). The SSC essentially acts to reduce the amount of time taken to produce the maximum force and plays a fundamental role in change of direction ability, sprint and jump performance (Markovic and Mikulic, 2010; Slimani et al. 2016; Wang and Zhang, 2016). Evidently this training enhanced U16 jump performance between October and January with a 2 – 6 % improvement observed for all jumps, except the single leg vertical jump which saw a negligible <1 % decline in performance. The same was reported by Bianchi et al. (2019): they found two plyometric sessions per week improved jump performance by 2 - 6 % in elite youth soccer players. This may suggest that had more players been sprint tested in January, sprint performance would have mirrored similar improvements to power.

Eccentric strength improved significantly, as shown by the Nordic Curl results in table 15. By incorporating rebounding plyometrics into their program, the U16 squad may have experienced double the eccentric muscular activity which plays a crucial role in the SSC (Bianchi et al., 2019). This

had a positive effect on eccentric strength, as indicated by the Nordic results. Furthermore, unilateral and bilateral bodyweight resistance exercises, including the Nordic Curl, were included in their training program to enhance hamstring strength. It is important to acknowledge the learning effect of this test. The NordBord was introduced for the first time at the start of the season, therefore players will have become more familiar with the equipment which may have increased their eccentric strength results. Subsequently, it is difficult to conclude that this improvement was a direct result of increased hamstring strength, though this likely did contribute largely.

Evidently, the U16 squad are training at an appropriate intensity as they have elicited improvements in strength and power between October and January. As they progress through the season and levels of play, it is important to gradually apply overload through the intensity, volume and frequencies of strength and power training sessions to encourage continuing improvement and physical preparedness. The academy also did not neglect the need to transfer these physical qualities into technical ability as they partook in two technical sessions per week, assisting them in their journey to professional level.

4.3.2 U18 Squad Analysis

Testing completion across both time-points was slightly more successful in the U18 squad than the U16 group. Limitations hindered the results in terms of participation numbers and meant no MAS testing could be completed. Following the October testing results, each player was informed of their strengths and weaknesses and prescribed exercises to maintain and improve these qualities. These individualised training programs were more appropriate than a general squad program for the U18 squad, as they already had built a solid base to work from and were looking to improve specific physical attributes.

Between October and January, the results highlighted a significant decline in agility and a non-significant decline in sprint performance (table 16). However, the small participation numbers reduce the reliability of results as they do not accurately represent the whole squad. The U18 power and strength results in table 16.1 illustrate a general improvement in results in January compared to October. Each week, the U18 squad carried out four indoor movement mechanics and plyometric training sessions and three strength sessions in the gym to encourage this development.

The dose-response relationship, discussed previously, emphasised the need for a sufficient dose to stimulate a response. The significant improvement in hamstring strength displayed in table 16.1 proves that training elicited a positive response. The positive implications of increased hamstring strength assist players in reaching their full potential as they become more elite. However, it is still important to consider the learning effect discussed previously.

The physical demands of training and matches were similar between October and January as shown in tables 17 and 18. There is a jump in average training data to match data, however, periodisation of training must be considered, as displayed in table 25. However, by adding a few sprints into training sessions this would increase both the total distance and distance covered in high-intensity zones in training, narrowing the gap between training sessions and match-play, therefore decreasing injury risk and increasing chance of success.

4.3.3 Reserve Squad Analysis

Across October and January, the Reserve squad had the greatest completion rate, assisting comparisons and reliability of results. Following October, individuals were assigned specific S+C programs to improve highlighted weaknesses; therefore, it was hypothesized that improvements would be observed in January.

The January findings show a decline in COD performance, though all other speed parameters significantly improved between October and January (see table 19). However, only 4 players were present for October and January COD testing; therefore, the decline in performance is likely not a representation of the whole squad. In correlation with the sprint results, all measures of lower limb power improved. This indicates a positive relationship between the S+C program and speed and power capacities of Reserve team players. Evidently, the Reserve squad were working with an appropriate load, i.e., dose, in the gym to elicit a positive response. Pitch training differences displayed in table 22 likely had further positive impact on the speed and power results. The lead-in to January testing differed to October in terms of distance covered at higher speeds: the significantly greater exposure to high power movements and opportunity to develop faster running biomechanics in training successfully translated into physical testing results.

Strength is a fundamental component of a soccer player’s physical profile for performance and injury prevention. The hamstring strength results prove a significant improvement in isometric strength was attained between October and January, however eccentric strength declined slightly. As a predominantly eccentric sport, it is possible that the players were suffering eccentric fatigue on the day of testing. Similar to the U18 squad, many components of testing were not kept consistent between October and January due to the difficulties of carrying out physical testing in a practical soccer setting. For one, the testing day differed: ideally testing should be carried out on a day after light training to minimise fatigue; however, this is not always possible. Additionally, order of tests was not kept consistent. The different order of tests can influence the results positively through the effects of post-activation potentiation or negatively through muscular fatigue (Weber et al. 2008); however, no record of order of tests was recorded or kept consistent to confirm this theory.

The Reserve squad exhibited physical improvements from the pitch and gym training sessions. To assist in progression to First Team level, it is important to continually increase the physical demands of these sessions to promote further development.

4.4 Reserve Squad to First Team Transition

A minute percentage of youth soccer players reach professional level. Calvin (2017) reported a mere 180 of the 1.5 million (i.e., 0.012 %) youth players involved in organised soccer will make it as an English Premier League professional or make a living from the sport. Furthermore, less than 0.5 % of players who enter academy soccer at 9 years old will make it to professional level. Nowadays, players are not just competing with their national counterparts but also the annual influx of international players. This monumental attrition rate from academy through to professional level highlights how competitive the sport of soccer really is. For those players who have excelled to Reserve team level, the competition is not over yet, in fact, this is arguably the most critical stage.

At this stage, a strong physical profile is a pre-requisite. Reserve team players must prepare to transition from a one-match-week schedule to up to a three-match-week schedule. How these players are physically and mentally prepared for this leap is up to the coaches, sports science and playing support staff. In modern soccer, ability to recover from match play is considered a determinant of subsequent performance (Mohr, Krustrup and Bangsbo, 2005). In a single season it is common for soccer teams to compete in 50 to 80 matches within a 40-week period, with some teams competing in three matches in a single microcycle (Carling and Dupont, 2011; Carling, Le Gall and Dupont, 2012; Dellal et al., 2015), emphasizing the need for recovery. A meta-analysis by Julian, Page and Harper (2020) reported increased match congestion to have a negative impact on distance covered in higher speed zones as well as technical performance and tactical cohesion with team-mates, due to mental fatigue.

By examining training and match differences between the Reserve team and First Team, evaluation of the Reserve team preparedness to progress can take place.

On average, First Team training sessions seem significantly less intense overall than the Reserve squad sessions (table 26). This is surprising as the natural hypothesis would be the reverse; in theory, training intensity should increase with the level of play. However, when you investigate these training sessions in greater depth, and consider match congestion, this overview may not be a true representation.

The First Team and Reserve squad seasons differ considerably. With the several leagues and competitions that the First Team are involved in, match prevalence across the season is much greater than at Reserve level. Resultantly, many training sessions are tailored to lead-in and lead-out of matches throughout the week; they are not as intense to cope with the increased match workload. The First Team played two to three matches per week whereas the Reserve squad were only playing one match a week. For this reason, a table was made based on a 'typical week' for each squad to examine the weekly demands in more depth and determine whether the Reserve squad are physically prepared to move up to the next level of play (see table 30). This was based on a two-match week for the First Team.

Both squads follow the same periodisation structure on the lead-in to matches: strength sessions (MD -4), endurance sessions (MD -3), speed sessions (MD -2) and reaction sessions (MD -1). This is, of course, the 'ideal' scenario. However, the First Team often only have a one or two- day lead-in to a match, thus training periodisation was adjusted accordingly. Typically, MD-3 was deemed the most intense session type, focusing on improving the aerobic and anaerobic energy systems with fitness runs and open match-play built-in to the sessions. Given both teams follow this structure, a comparison of each training session category was carried out between squads (see table 27).

The data in table 27 proves, for both squads, the most intense session type to be resistance (MD -3), followed by strength (MD -4), speed (MD -2) and finally the reaction sessions (MD -1). The table also shows very similar reaction sessions between the two squads, with no significant differences present. Despite the same MD -2 session duration, the First Team covered a significant 1 km more distance on average, thus work at a greater intensity throughout each session. The sessions with the highest intensity are resistance sessions; however, the First Team resistance sessions cover significantly more distance than the Reserve squad and last 9 minutes longer, on average. Although the First Team run further in these sessions, the Reserve squad do cover slightly more distance over 5 and 7 m/s, respectively. The Reserve squad strength sessions were a significant 20 minutes longer, yet they covered approximately 700 m less than the First Team. Subsequently, the Reserve session intensity was significantly less than the Reserve squad.

With these differences in mind, it draws attention to what a 'typical week' for each squad may entail, as shown in table 30.

Table 30: The typical weekly schedule for the Reserve Squad and First Team.

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Reserve Squad	MD -1	***Match***	*Recovery*	Off	MD -4	MD -3	MD -2
First Team	MD -3	MD -2	MD -1	***Match***	*Off*	MD -1	***Match***

Using the data from table 27 and applying it to the 'typical week' above enables calculation of the weekly demands posed on each squad which is displayed in the table 31 below.

Table 31: The weekly physical demands that the Reserve squad and First Team experience.

	Total Duration (mins)	**Total Distance (km)**	**Average Distance per min (m/min)**	**Average Max Velocity (m/s)**	**Total Distance >5m/s (m)**	**Total Distance >7m/s (m)**
Reserve Squad	422.33	27.63	62.94	7.32	1154.01	299.35
First Team	504.73	38.08	71.61	7.44	929.83	156.07

Note: Data displayed is based on the schedules shown in table 30 and training category data displayed in table 27.

Although the data in the table above is an average of averages and, therefore, is not the most accurate, it does provide an insight into the differing physical demands between squads. The most notable differences in the typical week for each squad is the greater total duration and total distance covered by the First Team. The 82.5-minute and approximately 10.5 km extra covered by the First Team underlines the one match difference between squads during a 'typical week'. This may confirm that the main jump between Reserve team level and the First Team is match demands. Based on the data, it may suggest that the Reserve squad are not being physically prepared for First Team level and risk being released from the club. Perhaps a method to bridge the gap would be to introduce a bounce game mid-week for the Reserve squad. This would increase the weekly distance covered and match-minutes whilst reducing injury risk upon progression, increasing each player's chance of success. Some coaches may be concerned that this would hinder performance in their own league matches. However, it is important to keep in mind that the primary aim for developing soccer players is their development and not always the match result.

Despite greater distance and duration in the First Team, the Reserve squad did cover more high-intensity distance, primarily in matches. This was not as hypothesised; literature commonly recognises the increase in high-intensity distance with level of play. This is positive for the Reserve squad as it shows they can withstand the First Team high intensity demands. High intensity difference in matches may be due to the First Team dominating most of their matches in the 2019/20 season as they lifted three trophies. The Reserve squad likely had to compete more for possession in their league. This difference in HSD also suggests more tactical intelligence, game awareness and energy-efficient play in First Team soccer.

As stated for the academy age groups progressing to Reserve team level, physical capacities are only one aspect of the game needed to be selected to work towards top professional level. Technical ability, tactical understanding, game awareness and training attitude are all required to achieve top professional status. These qualities must also be a focal point in training alongside physical attributes.

The most obvious discrepancy between Reserve team level and the First Team is match prevalence: one game per week to two to three games per week is a considerable jump to make and puts a player at risk to injury. Introducing a mid-week bounce game into the Reserve schedule should assist in bridging the gap and physically preparing players who are ready to progress to top tier professional soccer.

4.5 Practical Applications

Training and match data comparisons across both time-points (October and January) highlighted a discrepancy in high-intensity distance across the academy squads: significantly less high-intensity distance was covered in training than matches. Although training periodisation reduces the average, there is still a large spike in matches compared to training on average which may increase injury risk. Perhaps increasing the dimensions of small-sided games and other drills in training would encourage more high- speed running to reduce the spike observed in matches. Intensity of small-sided games is affected by factors such as pitch size, team size, rules and coach encouragement (Reilly and White, 2004). A larger pitch size with smaller team sizes will permit higher exercise intensity (Reilly and White, 2004). Furthermore, Jones and Drust (2007) found that reducing team size from 8v8 to 4v4 significantly increases the number of ball contacts among youth soccer players, therefore this would be beneficial to multilateral development: improving fitness and soccer-specific skills.

Another option may be to incorporate two to three additional half-pitch sprints, on the appropriate training days. This would likely help squads physically prepare for the next level of match-play, as well as improve NM activation through the increased exposure to high-speed running which may enhance power and speed qualities.

The discrepancy in high-intensity distance between training and matches was not as large in the Reserve squad. However, there was a clear barrier and limitation to the Reserve squad successfully transitioning to the First Team: match prevalence. The most obvious jump between the squads was the First Team competing in two to three matches per week compared to one per week for the Reserve squad. Table 31 highlighted that the First Team covered approximately 10 km more total distance than the Reserve squad on an average 2-match week. Of course, this gap would widen further on weeks with three matches. With the knowledge that injury prevalence increases with a sharp increase in external load, it reduces the chance of Reserve team players achieving a successful transition. Therefore, to bridge the gap, it may be suggested to incorporate a weekly bounce game to the Reserve squad schedule in the second half of the season. The following section outlines possible methods to carry out the additional game-time.

4.5.1 "Bridging the Gap"

Soccer clubs are largely results-driven environments, where match score-lines are accepted to represent the squad's success and development. However, this can cause coaches and surrounding staff to develop 'tunnel vision', resultantly neglecting key aspects of athlete development. In this instance, for the Reserve squad, there may be barriers when attempting to implement additional match-play in the form of a bounce game. The coach, for one, may fear that this would cause additional fatigue in players and negatively impact official league and cup match performances. Of course, this is a consideration as the increased match-play may negatively impact performance short-term, but will improve physical robustness and resilience long-term, promoting optimal performance in matches and increasing each player's chance of success.

Another barrier may be squad numbers in training. A few Reserve squad players are only at the club a few days a week as they are out on part-time or full-time loans. As a result, there are not always enough players to field an 11-a-side full-sized pitch match. Injuries also reduce the number of available players. Therefore, a suggestion to overcome this barrier would be to select pitch dimensions with the same area per player as an 11-a-side match on a full-size pitch. For example, an 11-a-side match on a 100.58 x 64 m soccer pitch provides an area of approximately 293 m2 per player; a 7-a-side on an 82 x 50 m pitch provides the same area. This will encourage mirroring demands of a match on a full-size pitch. Duration of the game can also be adapted to allow for coaching time by playing 3 x 20-minute thirds, for example. This would also allow players additional rest periods whilst they adapt to the additional weekly game- time. To progressively increase players resilience to cope with the stressors an additional match imposes, duration could be gradually increased from 2 x 20-minute halves to 3 x 20-minute thirds, to 4 x 20-minute quarters as they work towards 2 x 45-minute halves. This may assist coach investment in this development plan as the reduced duration to begin with would minimise fatigue and the potential for negative impact on official match performances.

More research needs carried out in this area, perhaps examining the effectiveness of the implementation of a bounce game in Reserve team development and success.

4.6 Limitations

4.6.1 Coronavirus Pandemic

This study's findings were limited due to various factors. The most obvious limitation being the Coronavirus pandemic. The initial aim of this study was to examine and compare the physical capacities of squads across an entire season. However, this was not possible as soccer activities ceased due to the pandemic. Resultantly, no May testing could take place and so only training and match data up to the January testing were included in this study.

4.6.2 Physiological Testing

Testing Day

The testing protocols themselves were also subject to limitations. As mentioned in the discussion, the content of the days prior to testing were not kept consistent across squads or between time-points. It was intended that each squad would have the day off to rest before testing. However, due to uncontrollable factors such as the weather, changes in schedules and loan player absences (to name a few), this was not always possible. In some instances, players undertook different tests on different days over a week to two weeks. No wellness or muscle soreness monitoring was carried out prior to testing; therefore, it is likely that fatigue levels of players within and between squads differed across all testing.

Circadian Rhythm and Post-Activation Potentiation (PAP)

In a practical soccer environment, physical testing must be efficient due to limited time allocated by coaches and the use of popular resources required by other squads. Therefore, testing ran in the most time-efficient way meaning tests were performed in different orders between squads and players within squads: each squad was split into groups which rotated round each physical test: some players performed CMJ testing prior to hamstring strength on the NordBord and vice versa. Additionally, due to space and time restraints, one squad may have undertaken sprint and MAS testing outside while the other squad undertook strength and power testing indoors, before switching. This efficiency comes at the sacrifice of reliability of results as the different order of tests means that either post-activation potentiation (PAP) or fatigue may have positively or negatively influenced results, respectively. PAP refers to excitation of the NM system following a short-bout of high-intensity exercise, such as a heavy back squat, which can enhance acute power production. For example, Weber et al. (2008) found VCMJ performance to improve several minutes after heavy back-squats. Thus, the variation in test order between participants may have influenced results.

Time of day of testing also varied between squads and time-points due to time limitations as well as weather. For example, the Reserve team consistently performed physiological testing in the morning, whereas the academy squads sometimes only had access to the testing equipment in the evenings.

Circadian rhythm is the body's response to light and darkness and is known to affect physical performance. Peak body temperature occurs in late afternoon and influences several physiological functions, including improving the actin-myosin interaction in muscular performance (Reilly, 1990; Reilly and Brooks, 1982).

Inter-tester Variation

Each squad has their own support staff that carry out testing and with that, raises the concern of inter- tester variation and reliability. It is important to note that all testing staff were briefed on correct protocols to minimise variability; however, inter-tester reliability must still be taken into consideration. Fortin et al. (2012) reported reliability of results to vary between 56 % and 82 % when 50 physical therapists were carrying out postural assessments. They also reported a reduction in variability and increase in reliability of results as testers became more experienced and advanced.

January Testing Incompletion

The academy January testing was not completed because of strict time constraints and harsh weather conditions. The harsh weather conditions continued for over a month thus outdoor testing was unable to go ahead, hence low participation numbers in sprint testing. The academy, however, did manage to carry out an increasing-intensity running test to measure true maximum heart-rate in these players. As this test took the place of the MAS testing in the allocated testing time, MAS results were not able to be obtained.

Statistical Analysis

Participation numbers were very low in some physical tests; therefore, effect size was calculated using partial eta squared. The ES values are limited as they were calculated across all squads and not between each individual squad, therefore it is not clear which age group had the biggest effect on results.

4.6.3 GPS Data

The methods highlighted varying GPS units between squads. A GPS validation study of these units was intended to be carried out during the May testing period. However, due to the soccer season's premature cessation, this validation study was unable to be carried out. As this was unable to go ahead, training and match comparisons between the Reserve, U18 and U16 squads may not be absolutely accurate.

Furthermore, GPS accuracy is known to decrease with increasing speeds (Coutts and Duffield, 2010); therefore, maximum speed values in training and matches may not be accurate.

The large variation in weekly training structure between the U16, U18 and Reserve team squads limited the training category data comparisons. Only the main U16 and U18 squad training sessions were included as there were additional skills and fitness sessions for selected players on selected days, but these were not consistent throughout the microcycles. Therefore, these extra sessions were not relevant to include as would not represent the training load of the squad as a whole. Resultantly, the training loads for selected players may have actually been greater than reported, thus the validity of the analysis and comparisons may be questioned.

4.7 Future Research

This study proves that a gap is present in the literature. Youth academy and adult professional soccer are commonly examined as separate entities in literature, and rarely refer to the transition between the two. With the substantial attrition rate observed between academy and top-tier professional soccer, future research should examine the transition between the two in greater depth, providing possible explanations for this attrition rate.

Additionally, the training data referred to in this study represented all activity performed between the start and finish time of each session, not taking rest periods, coaching or ball-collection time into consideration, as well as the content of each squad's drills themselves. Resultantly, some of the data displayed may have not shown the true intensity and make-up of each session. By investigating the content of each squad's training sessions in greater depth, this would enable further insight as to whether squads are being prepared in training for the next level of play.

This study's match data were contrary to literature as high-intensity distance did not always increase with level of play. However, the data is limited as they are averages of all matches and do not take tactical differences into account. In future, it would be worthwhile to record the number and distance of sprints observed in each squad's matches to provide further insight to the high-intensity match demands experienced as level of play increases.

As discussed throughout, both a spike in high-intensity distance in academy matches compared to training and a jump in total distance covered between the Reserve squad and First Team were observed in this study. Literature commonly acknowledges the increased injury risk with an increase in external load, therefore future research should investigate injury prevalence in players transitioning between squads. This would underline any discrepancies between squads and validate the preparedness of the athlete to progress to the next level.

A strong physical profile for an athlete is desired for both performance and injury prevention purposes. For example, hamstring strength has been addressed in this study and the role that it plays in hamstring injury prevention, however this study did not monitor injury rates throughout the season across any of the squads. This topic would be interesting to address in future research to quantify the reduction in risk with increase in hamstring strength.

5. Conclusion

This study proves that a gap is present in the literature. Youth academy and adult professional soccer are commonly examined as separate entities in literature, and rarely refer to the transition between the two. With the substantial attrition rate observed between academy and top-tier professional soccer, future research should examine the transition between the two in greater depth, providing possible explanations for this attrition rate.

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