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**Determination and comparison of anthropometric, physiological and psychological performance measures in elite youth Rugby Union players at four different stages of professional development across three time points during a competitive season and the longitudinal changes of each age group.**

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## ABSTRACT

Understanding the development of talented youth Rugby Union players in Pathway and Academy settings is important for their continued preparation and support to aid the transition of these players into professional rugby (Kobal, et al., 2016).

The aims of this study were to: (i) document and compare anthropometric, physiological and psychological capacities in Scottish Rugby Union (SRU) elite players between 4 developmental levels and (ii) compare within each level across the season. With institutional ethics approval, Under 16 (U16, N=18), Under 18 (U18, N=16), BT Academy Stage 2 (BAS2, N=9) and BT Academy Stage 3 (BAS3, N=12) players completed 3 testing points over 2016-2017 season (pre, mid and post). Measures of *anthropometric* (body mass, percentage body fat and fat free mass), *functional movement* (tuck jump), *lower body power* (counter movement jump (CMJ)), *strength* (3 repetition maximum (RM) squat, bench and chin), *speed* (10m & 30m sprint, 10m momentum), *aerobic fitness* (YoYo Intermittent Recovery Test-1), *anaerobic endurance* (Repeated Sprint Ability), *agility* (505) and *psychological* (Sports Mental Toughness Questionnaire (SMTQ)) characteristics were completed. In the pre-season test results indicated that most statistically significant differences between playing levels occurred between BAS3 v U16 and BAS3 v U18 levels in body mass (95% Confidence Intervals of difference (2.1, 29.5 kg) and (3.2, 33.8 kg)) respectively, FFM ((1.4, 23.0 kg) and (6.4, 28.2 kg)), CMJ ((8.0, 18.6 cm) and (1.2, 18.6 cm)), when allometrically scaled, 3RM Squat ((250.4, 527.4 AU) and (175.6, 483.8 AU)), 3RM Bench ((40.6, 71.9 AU) and (28.4, 61.8 AU)), 3RM Chin ((84.5, 297.9 AU) and (73.1, 296.4 AU)) and 10m Momentum ((14.1, 169.4 kgm/s) and (25.8, 199.4 kgm/s)). BAS3 were significantly faster over 30m than the U16 cohort (-0.53, 0.04 s). A similar pattern was evident in mid and late season. At the mid-point of the season it was apparent after analysing test scores that, BAS3 and BAS2 had significantly greater power than U16 (CMJ, (4.3, 19.3 cm), (2.6, 17.6 cm)). The BAS3 cohort during testing recorded a greater Total Mental Toughness score than

the U16 cohort (0.1, 6.0 AU). Repeated Measures ANOVA showed no statistically significant changes for agility, speed, aerobic or anaerobic fitness across the season at any playing level although large effect sizes were evident. The U16 Whole Squad significantly improved 3RM Bench (2.0, 16.7 kg) across the season. Total Mental Toughness scores improved for U18 (0.1, 6.0 AU), BAS2 (2.0, 7.0 AU) and BAS3 (0.1, 16.0 AU). As hypothesised, BAS3 recorded the most differences compared to the lower pathway levels (Darrall-Jones, et al., 2015). At each time point the BAS3 players were stronger, had greater lower body power and lean mass; however they did not demonstrate as having greater agility, aerobic fitness or anaerobic endurance than the junior players. Where no differences were found in characteristics between Academy and Pathway levels, and no changes across season, even where differences would be expected (e.g. body fat percentage and anaerobic endurance), greater focus can be made on these aspects of development in training.

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## ABBREVIATIONS

| | |
|---|---|
| 1RM | 1 Repetition Maximum |
| 3RM | 3 Repetition Maximum |
| 505 L | 505 Agility Test Left Foot |
| 505 R | 505 Agility Test Right Foot |
| 95% CI | 95% Confidence Intervals |
| ACL | Anterior Cruciate Ligament |
| ANOVA | Analysis of Variation |
| AU | Arbitrary Units |
| BAS2 | BT Academy Stage 2 |
| BAS3 | BT Academy Stage 3 |
| BF (%) | Body Fat Percentage |
| BW | Body mass |
| CM | Centimetres |
| CMJ | Counter Movement Jump |
| Diff | Significant Statistical Difference |
| FFM | Fat Free Mass |
| ISAK | International Society for the Advancement of Kinanthropometry |
| KG | Kilograms |
| KGM/S | Kilogram-metre per second |
| M | Metres |
| ML/KG/MIN | Millilitres per kilogram per minute |
| MSFT | Multi-Stage Fitness Test |
| MTI | Mental Toughness Index |
| N | Number of Participants |
| PERF/BW | Performance per body mass |
| RSA | Repeated Sprint Ability |

| | |
|---|---|
| RSA%D | Repeated Sprint Ability Percentage Decrement |
| RSAMT | Repeated Sprint Ability Mean Time |
| S | Seconds |
| S.D. | Standard Deviation |
| SMTQ | Sports Mental Toughness Questionnaire |
| SRU | Scottish Rugby Union |
| TJ | Tuck Jump |
| TMO | Television Match Official |
| U14 | Under 14 |
| U15 | Under 15 |
| U16 | Under 16 |
| U18 | Under 18 |
| U20 | Under 20 |
| U21 | Under 21 |
| V | Versus |
| $\dot{V}O_2max$ | Maximal Aerobic Capacity |
| YoYo IRT-1 | YoYo Intermittent Recovery Test 1 |

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Finally, to my parents whose support has been instrumental in assisting me to complete this MSc.

## AUTHOR'S DECLARATION

I declare, except where explicit reference is made to the contributions of others, that this thesis is the result of my own work and has not been submitted for any other degree to the University of Glasgow or at any other institution.

Signature:

Printed Name:

# 1. SYSTEMATIC LITERATURE REVIEW

## 1.1 Rationale

Given that the nature of Rugby Union is very unique in that differences in positional demands across the team results in the need for a variety of body statures and abilities being a requirement for optimal performance. Within existing current literature there has been an extensive body of work completed for youth Rugby League Academy players to give an insight of how these physical characteristics differ between positions. This will assist in completion of this thesis as there is limited evidence from Rugby Union. The aims of this review are to examine the current literature and provide a greater understanding of the performance measures that exist in youth Academy rugby players and the changes in performance measures across a season.

This review will attempt to identify the performance measures that are worthy of exploration in youth and adult Rugby Union players. It will also endeavour to identify any seasonal longitudinal changes in performance measures across different age groups in elite, Rugby League and Rugby Union.

## 1.2 Methods

The protocol used to conduct this systematic literature review follows the document published by Preferred Items for Systematic Reviews and Meta-Analyses: The PRISMA statement (Moher, et al., 2009).

An eligibility criteria set for this study was field based sports of a similar nature to Rugby Union. As previously indicated, the unique nature of this sport rules out the majority of field based team sports, leaving predominantly studies conducted within Rugby League. Differences between elite and sub-elite players within adult Rugby Union and League were included for the study.

The systematic review of the current literature was completed from the 21st of March until the 17th of April 2017. The search was carried out through the online databases MEDLINE (Ovid), PubMed and Google Scholar. The version of MEDLINE (Ovid) selected was from 1946 until the third week in March 2017.

Examples of the key words or phrases which were chosen to achieve an appropriate systematic review:

1. exp Athletic Performance/ or exp Sports/ or exp Sports Medicine
2. ((athlet* or sport*) adj3 performance).tw
3. 1 or 2
4. Rugby.tw
5. 3 and 4
6. (yoyo or yo-yo or irt-1 or irt1).tw
7. 5 and 6

Note: exp was selected to explode the topic heading to include all sub headings and * represents truncations allowing for a larger search.

This was one of the searches carried out on MEDLINE (Ovid). Similar searches were carried out altering the key words to attempt to search other published works. Examples of different key words which were used in these searches were youth and anthropometry or anthropometric. The keywords were repeated within other electronic databases.

Initially, article titles and abstracts were read to ensure selection of relevant studies. Once the selection process was completed, the chosen papers were read in full to confirm that they followed the set inclusion criteria. As previously mentioned, the inclusion criteria for this review were studies conducted with youth or adult Rugby Union or Rugby League players and which were attempting to identify the performance measures of their chosen athletes. Longitudinal studies of performance measure were also included for review as this would address the secondary aim of the study. Meta-analyses and review papers were included within the review. During the process of reading the selected studies duplicates were removed.

Participation, Interventions, Comparison, Outcomes and Study Designs (PICOS) were removed from the selected papers. This was completed to allow for a greater understanding of the current literature within this field and allow a hypothesis to be established.

## 1.3 Results

The systematic review search resulted in two hundred and twenty two studies with two coming from external sources. After screening to remove duplicates and papers not relevant to this study, this number was reduced to twenty-seven. The process of this systematic review has been illustrated below, Figure 1:

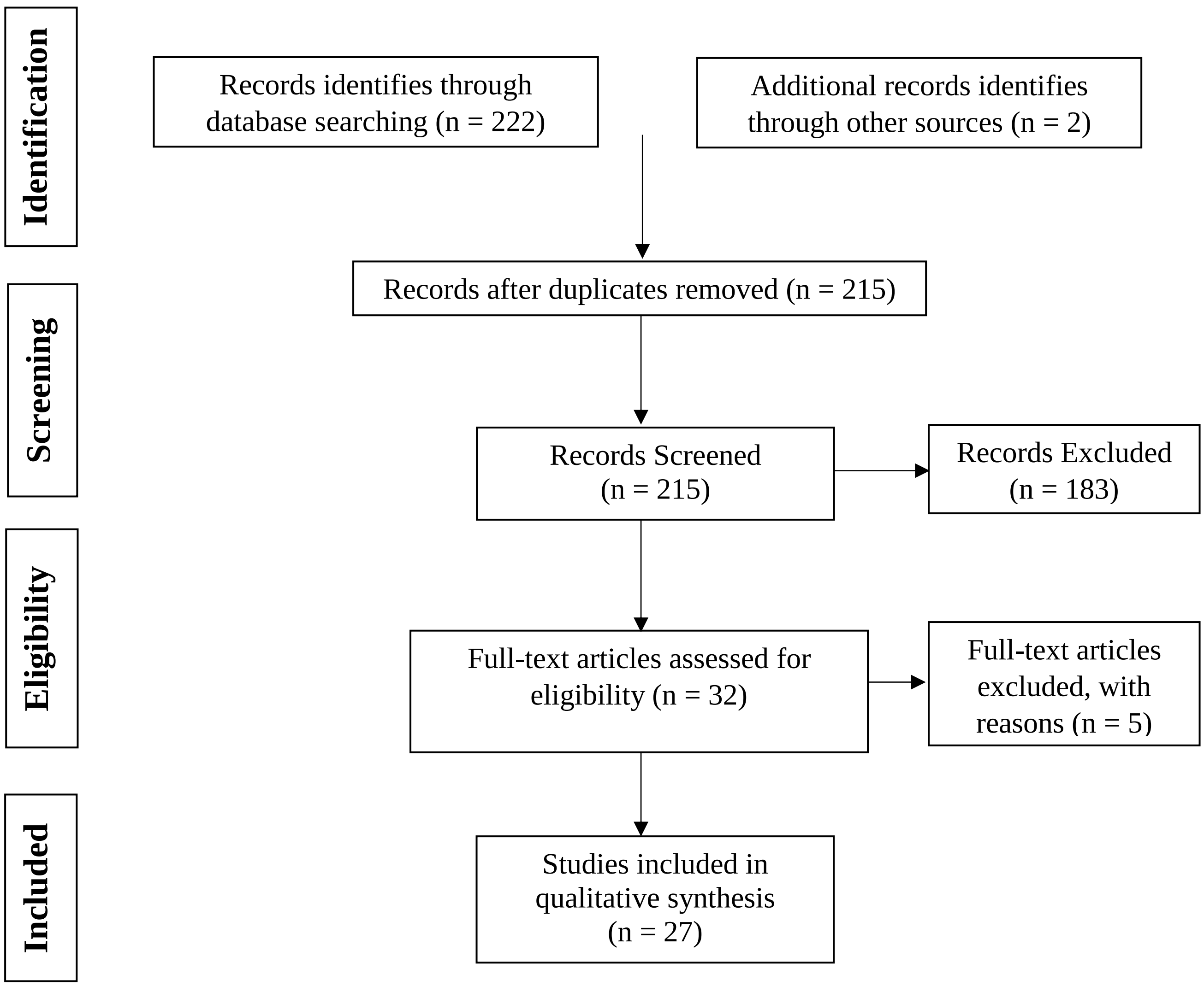



*Figure 1: Systematic Review article identification Flow Chart*

## 1.4 Search Summary

There were two modes of rugby included within this systematic review namely Rugby Union and Rugby League. Longitudinal studies of performance measures were also included in the review for Rugby Union and League. Papers published after 1995 were specifically included as this was the year in which Rugby Union turned professional. Finally, review papers were included in this literature review. There were a total of twenty-seven studies included: nine from Rugby Union, nine from Rugby League and nine longitudinal studies (both Rugby Union and League). Across all studies there were 4392 participants competing at a variety of levels from Schoolboy to Elite Professional players. Their ages ranged from 16 to 30 years old. The reason for this wide age range is due: i) to the fact that most Academies for which players are selected begins at U16 level and ii) A proportion of the studies included, looked at professional players who will compete until approximately thirty years of age. A breakdown of the studies included in this review can be found in Appendix 8.1.1.

## 1.5 Rugby Union Study Summary

A detailed summary of Rugby Union studies are illustrated in Appendix 8.1.2.
The level at which the players from the nine studies played varied from elite youth teams to senior levels – professional and sub elite. These group studies were completed within different countries which provides a rounded representation of the physiology and anthropometry of Rugby Union players worldwide. As far as the researcher is aware there has been no study which has measured a psychological output in Rugby Union studies testing across such a large battery of tests.
The majority of the studies tested physiological and/or anthropometric measures. Only one study could be found that tested anthropometry (Fontana, et al., 2015). This was one of two studies which tested only adult players. The other adult study was conducted in New Zealand at the introduction of professional rugby by Quarrie, et al., (1996). Both of these studies can be included for comparison with this study and analysis due to them including a similar linear progression which is being

explored in this current study. This was due to some of the athletes used in this study, who are currently playing at the highest level of adult rugby, despite still being an Academy player.

Rugby Union is played by fifteen players which contains two positonal splits which groups them as forwards or backs. The positional groups are subdivided further to forward positions of: *front row*: loosehead prop, hooker and tighthead prop; *second row:* two locks; *back row*: blindside flanker, openside flanker and number eight and backs into: *half backs* or *inside backs*: scrum halves and stand offs; *midfield backs*: inside and outside centre and *outside backs* or *back three*: right and left wing and a fullback. Before the game turned professional there were a large number of studies looking at the physiology and anthropomteric qualities of Rugby Union players which is well documented in a review paper by Nicholas (1997). Of all the studies which are included in this review, five of them compared forwards and backs, three within the five compared these positions across different age groups – both types of study will allow direct comparisons to be made as this is the primary aim of the study. The final Rugby Union study used more specific postional groupings, similar to the ones highlighted above, to compare their data (Quarrie, et al., 1995). Despite this, the data are still able to be included as it provides information on specific differences between players.

## 1.6 Rugby League Study Summary

Currently there have been more studies published in Rugby League than Rugby Union reporting on the physiological and anthropometric characteristics of junior players. The majority of papers come from Australia (Gabbett, 2000; Gabbett, 2002; Gabbett, 2005) and the United Kingdom (Till, et al., 2013; Till, et al., 2014; Till, et al., 2014), albeit the three Till papers are all longitudinal studies. A detailed review of the Rugby League studies can be found in Appendix 8.1.3. Rugby League has a similar positional split to Rugby Union as it has forwards and backs but within the forwards there are no flankers.

From the nine Rugby League studies which measured various performance measures at one given time point only three of them focused solely on youth athletes. The other six were split: three adult only and three youth to adult. Six studies looked at both physiology and anthropometry performance measures. Only three of the studies used a comparison split of forwards and backs (Cheng, et al., 2014; Gabbett, 2000; Kirkpatrick & Comfort, 2013) and the Kirkpatrick study was the only one to look at youth players.

## 1.7 Longitudinal Study Summary

To the author's current knowledge there has only been one study which has measured the longitudinal changes of both physiological and anthropometric measures over a prolonged period for Rugby Union players. This was completed by Lombard, et al., (2015). Lombard's publication in 2015 was a very comprehensive study lasting over thirteen years which tested 453 U20 South African Rugby Union players. There were only two other studies which looked at Rugby Union athletes, both of these were based on adult populations (Appleby, et al., 2012; Smart, et al., 2013). As previously highlighted, there is currently more evidence based on youth Rugby League players. Five of the six longitudinal Rugby League studies were based on youth athletes and tracked the seasonal changes that occurred. A more specific breakdown of these studies can be found in Appendix 8.1.4.

## 1.8 Findings

The number of studies in Rugby Union which aim to gain an understanding on physiological and anthropometric characteristics of youth athletes is lacking. Despite this from the studies which have been published it is apparent that performance measures do differ between age groups especially when comparing backs and forwards. In a study by Darrall-Jones, et al., (2016) it was concluded that U18 and U21 backs had on average lower body mass and skinfold thickness measures, were faster over 40m with various distance splits but generated lower momentum than forwards of the same age. Similarly, Darrall-Jones, et al., (2015) found that large effects sizes occurred for body mass within the following comparisons (U16 v U18 (-0.7); U16 v U21 (-1.5); U18 v U21 (-0.8)) and lower body power through vertical jump height (U16 v U18 (-1.1); U16 v U21 (-3.1); U18 v U21 (-1.5)). These effect sizes all are calculated by taking the younger cohort's data away from the older cohort's data, therefore a negative effect size indicates a better performance for the older cohort. The strength performance measures also showed large effect sizes when U18 players were compared to the U21. These findings clearly suggest that a linear progression across age groups in some performance outcomes exists. Kobal, et al., (2016) added weight to confirm these findings. Data from U15 through to National players showed improved aerobic fitness for the YoYo ITR-1 and speed times, across age groups. However, due to inconsistencies in testing procedures direct comparisons are difficult to make. A clear example of this 'inconsistency' was apparent when using the sum of skinfold sites to estimate body fat percentage. In the two Darrall-Jones studies they used eight sites to determine anthropometry however, Fontana, et al., (2015) used 6 sites. In conjunction with this, although the practitioners were fully qualified holding International Society for the Advancement of Kinanthropometry (ISAK) qualification, testing differences which can be attributed to human error may lead to anomalies in results. Albeit, Fontana, et al., (2015) found, that forwards had greater body mass (106.1±1.0 kg v 87.9±9.1 kg), body fat percentage (19.1±5.9 % v 12.4±4.6 %) and fat free mass (85.5±7.3 kg v 76.8±6.9 kg) than backs. An example of these inconsistencies was seen in a study carried out by La Monica, et al., (2016) where only three skinfolds sites were used and the study did not specify whether the practitioner was ISAK qualified. Despite this, the findings suggested that forwards had a higher estimated body fat percentage (12.6±4.2% v 8.8±2.1%) with a large effect size (ES) (1.1). This study also reported that forwards had a larger absolute squat score of 164.6±43.0kg compared to 108.5±31.5kg for the backs. These findings support other studies showing clear differences in performance characteristics between forwards and backs and across age groups. However, the inconsistency of testing highlighted, must be considered when making direct

comparisons for specific performance outcomes. It would however be reasonable to make comparisons to identify any common traits that are present.
Findings from Rugby League studies appear inconsistent especially when considering positional comparisons. In two studies by Gabbett (2005 and 2006), it was concluded that there were few physiological and anthropometric differences between positions. This contradicts findings from other studies conducted in Rugby League and Rugby Union where clear positional differences were evident. The reason for this contradiction is most likely due to Gabbett testing each playing positions compared to testing groups of similar positions. This is common to ensure adequate sample sizes allowing for a larger range of test scores. Kirkpatrick & Comfort (2013) studied the physiological and anthropometric characteristics within Rugby League players and found that forwards had greater body mass than backs (90.1±11.7 kg v 87.8±6.3 kg) and greater absolute strength scores. This was supported in age group comparisons carried out in Rugby Union studies by Baker (2002) who found that both body mass and upper body 1RM bench press increased as players progressed through the age groups. Inconsistencies in anthropometric data collection make it difficult, which is in agreement in the Rugby Union studies, make it difficult to draw direct comparisons. Two of the studies were looking to identify anthropometric data. However, one of these studies used Duel-Energy X-Ray Absorptiometry (DEXA) and the other used sum of 8 skinfolds to estimate body fat percentage. Skinfolds were collected by an ISAK qualified practitioner. Despite these different approaches both studies found clear differences occurring between positions. Cheng, et al., (2014) found body mass was greater for forwards compared to backs (92.6±12.2 kg v 80.9±7.1 kg) and had a higher estimated body fat percentage (16.1±4.8 % v 11.8±3.2 %).

Findings from longitudinal studies clearly show changes in physiological and anthropometric characteristics. Lombard, et al., (2015) collected data over a thirteen year period on U20 South African National represtative players. It was concluded that forwards were 22% heavier, 5% taller and 18% stronger compared to backs and that over the thirteen year period, stature did not change but strength and muscle endurance increased by 50%, body mass by 20% and speed times by 4-7%. This gives a very clear understanding of changes for U20 Rugby Union players on a relatively large battery of tests. However, there was no psychological element incorporated into the study to make any comparisons with the data from the current study. Till, et al., (2015) found that over a six year period the greatest changes between U16 and U17 age groups, 1RM Squat scores changed by 22.5±19.5% from U16 to U17 compared to 4.8±6.4% from U18-U19 and body mass increased from 76.4±8.4kg to 81.3±8.3kg from U16 to U17 playing levels. From the data, only one study looked at the seasonal changes in physiological and anthropometric characteristics; however, this looked at adult Rugby League players. This was mentioned as players from this study could be playing adult rugby either one of Scotland's professional teams, or in the top amateur league. It was concluded that during the early stages of the season the greatest increases were seen in maximum aerobic power, muscular power and the decreases in the sum of skinfold. Surprisingly, this trend was reversed towards the end of the season.

### 1.8.1 Aim

It is evident that there is currently limited knowledge on physiological and anthropometric characteristics of youth Rugby Union players and no information about psychological characteristics. Due to the highly physical nature of the sport it is extremely important to gain a fuller understanding of these properties to establish normative data between age groups and positions.

The aims of this study were to:

- document and compare anthropometric, physiological and psychological capacities in Scottish Rugby Union (SRU) elite players between four developmental levels.
- compare within each level across the season based on data collected from three testing points (pre, mid and post season).

# 2. INTRODUCTION

## 2.1 Overview of Rugby Union

Rugby Union's professional status is relatively young in comparison to other field based team sports. Only becoming professional in 1995, it has quickly become a leading global sport with 121 affiliated countries to World Rugby (Rugby Union Governing Body) with 8.5 million registered players worldwide (World Rugby, 2016). The games largest and most profitable competitions are organized directly by World Rugby. Included amongst these are the Rugby World Cup every four years with the next competition occurring in 2019, the HSBC Sevens World Series, U20 Junior World Cup and the Pacific Nations Cup. Rugby Union is predicted to become even bigger with the inclusion of the fast paced game of Rugby 7's into the Olympics. According to World Rugby, this will attract over 16 million new fans to the game. (Neilsen Sports, 2016).

On the 27$^{th}$ of March 1871 Scotland was home to the first ever international match against England which was held at Raeburn Place in Edinburgh. This match was viewed by 4000 spectators. Fifteen years later, Scotland was one of four countries which founded the original Rugby Union governing body, namely the International Rugby Football Board. Currently, there are only two professional teams in Scotland; Edinburgh Rugby and Glasgow Warriors. The tier that exist underneath this are four youth academies, with the two larger being associated with the professional teams. However, the top competitive league in Scotland is not professional.

Rugby Union is a high intensity intermittent team based field sport (Darrall-Jones, et al., 2015). The game is characterized by periods of strenuous aerobic and anaerobic activity followed by periods of sporadic recovery for players. It is estimated that the game is played at a work rate of 80-85% maximal aerobic capacity ($\dot{V}O_2max$) (Cunniffe, et al., 2009). There is a tendency for large collisions through tackling and ball carrying (Duthie, et al., 2003), rucks and mauls which are interspersed with periods of maximal sprinting, running, jogging and walking (Darrall-Jones, et al., 2016). Senior competitive matches are played over 80 minutes with two 40 minute halves. However, the actual time the ball in play has been reported to be between 35 and 45 minutes. (Lacome, et al., 2014). This is supported by an article published in 'The Roar' stating that in the 2011 Rugby World Cup, the average ball in play time was 35 minutes and 25 seconds. This is only 44.3% of the total game duration. The rest of the allotted time is lost to stoppages such as set piece, penalties etc. (Smith, 2012).

## 2.2 Positional Demands of Rugby Union

Each team is allowed fifteen players on the pitch at one time with eight replacements on the substitute's bench. However, the number of substitutes is determined by competition level. The fifteen players on the pitch are clearly separated into two distinct positional groups: eight forwards and seven backs. Due to the nature of the sport, as described in the previous section, there is a variety of positional demands. These variations allow for a large number of players to participate in the game. This point was acknowledged in a study by Lee, et al., (1997). Lee's study reported that Rugby Union allows players of differing body shapes and abilities to have a positive effect on the match.

The eight forwards can be sub-divided into smaller groups: *front row*: loose head prop, hooker and tight head prop; *second row*: two locks and *back row*: blindside flanker, open-side flanker and number 8. Likewise more specific positional grouping is evident across the seven backs: *half backs*: scrum half and standoff; *midfield backs*: inside and outside centre and *back three*: right and left wing and fullback. Each position has a specific role within the game's structure.

The forwards are predominantly involved in set piece plays, scrums and lineouts, where direct physical competition with opposition forwards is present. Whereas the backs play a freer flowing fast paced game in the open field with wider passes and longer sprints. (Austin, et al., 2011). Due to these positional demands it is well published that forwards are typically larger and stronger to cope with their close fought game style compared to the smaller faster backs (Duthie, et al., 2006). Olds (2001) published data which clearly showed the changes in body mass of players over the last centrury. It was published that forwards increased in body body mass on average from 92.7kg to 103.7kg and backs from 80.0kg to 84.7kg. More recent data has shown that both forwards and backs have increased in body mass, with backs showing a greater rate of change. Fontana, et al., (2015) published anthropometric data on elite Italian Rugby Union players and found that the average body mass for a back was 87.9±9.1kg. This increase in body mass from 2001 to 2015 could be attributed to the professionalism of Rugby Union and the way the style of play has chanegd as a result. Data from Lombard's thirteen year longitudinal study highlighted that U20 South African representative forwards and backs increased in height and body mass over the period of study. From 1998 to 2009 the forwards increased in height from 181±8cm to 188±8cm and body mass from 99±9kg to 108±7kg. Similarily, the backs increase from 172±5cm to 182±5cm and 74±10kg to 88±8kg over an nine year period (1998-2007). Not only did the paper publish increases in body stature and mass, but changes in strength, speed and power were also evident (Lombard, et al., 2015).

Using Global Positioning System (GPS) tracking technology it is estimated that players typically run between 5000m and 7000m a game (Roberts, et al., 2008). In a study by Cunniffe, et al., (2009) it was concluded that backs ran further than forwards and that they completed a higher number of maximal sprints, this could be attributed to the differences in style of play and stature of the different positions. In a review study by Duthie, et al., (2003) it was reported that upon direct testing of $\dot{V}O_2max$ backs possessed a higher aerobic capacity than forwards, when body mass was taken into account. This view point was supported in an unpublished work by Urquhart (2016), when comparing elite youth Rugby Union players it indicated that backs had a higher $\dot{V}O_2max$ (mL/kg/min) compared to forwards (52.6 and 50.7 ml/kg/min respectively).

## 2.3 Mental Toughness and Sports Performance

Clough, et al., (2002), provided an explanation which described mentally tough individuals and the advantages they have:

> *"Mentally tough individuals tend to be social and outgoing; as they are able to remain calm and relaxed, they are competitive in many situations and have lower levels of anxiety than others. With a high sense of self belief and an unshakeable faith that they can control their own destiny, these individuals can remain relatively unaffected by competition or adversity".*

Believed to being one of the most important differences resulting in improved performance between individuals, mental toughness has been an important focus for many other fields of work (Gucciardi, et al., 2015). These include surgery (Colbert, et al., 2012), business (Jones & Moorhouse, 2007) and law enforcement (Miller, 2008). This is due to the conception that mental toughness helps to maintain or improve performance, especially under pressure.

Mental toughness is a very common term used in sport but it is a concept which is poorly understood by coaches and athletes (Jones, et al., 2002). As a result of this poor understanding of the concept of 'mental toughness', research was increased by sports psychologists to gain a fuller understanding of success in sport and whether it can be attributed to a certain psychological trait (Bull, et al., 2005).

According to Jones, et al., (2007) the ability to maintain a high performance and overcome any adversity an athlete may face is believed to be aided by 'mental toughness'. As previously stated mental toughness is not only a term used in sport but also everyday life. However, specifically in sports there are perceived to be two components related to mental toughness which are important to improve performance: resilience and thriving. ‘Resilience’ is the process by which one adapts to significant adversity, or ones ability to regain and maintain previous high levels of performance (Masten, 2011). Spreitzer, et al., (2005) defined ‘thriving’ as the “psychological state in which individuals experience both a sense of vitality and a sense of learning”.

Previous studies that were carried out in relation to mental toughness in sport found that there is a definite link with anxiety and motivation levels. It is believed that when competition anxiety levels exceed a certain threshold there is a detrimental effect on an athlete’s performance, motivation and enjoyment for their sport (Patel, 2010). Confirmation of this exists in other studies, where athletes who scored high on mental toughness questionnaires, were able to regulate negative emotions such as competition anxiety (Jones, et al., 2007). Similarly, studies by Gucciardi & Jones (2012) and Mahoney, et al., (2014) stated that athletes who possess higher levels of mental toughness are more able to regulate emotions and create more positive emotions during athletic situations. The Gucciardi and Jones (2012) study looked at cricketers and their mental toughness profiles. They concluded that the cricketers with a ‘better’ mental toughness profile experienced competition anxiety at a lower level than those athletes who had lower mental toughness profiles. More recently Schaefer, et al., (2016) reported that golfers with low motivation profiles experienced higher levels of competition anxiety, consistent with other studies (Ntoumanis, 2002; Vallerand & Losier, 1999). Currently there is an ongoing debate about whether mental toughenss is the most important factor for sporting success. Gucciardi, et al., (2008) certainly believed it was as he reported that mental toughness explains how ‘good’ athletes become ‘great’ athletes. However, others believe that it is a combination of anthropometric, physiological and psychological characteristics (Crust, 2008) along with deliberate sport specific training that differentiates athletes (Ericsson, 1996).

## 2.4 Current Knowledge

These notable changes in physical and anthropometric characteristcs have become more prevelant as teams aspire to gain any form of advantage over their opposition especially after the game turned professional in 1995. Not only have the players changed in stature but the game has transformed into a much faster, more intense collision based sport. The Game Analysis Unit of the International Board reported straight after the 2011 Rugby World Cup on the number of changes the game has undergone. It reported that in 1995 there was an average of 37 scrums and 24 lineouts per game. This number of stopages has dropped dramatically to 27 scrums and 17 lineouts. Running in tandem with this the game has become faster and longer in terms of the average ball in play time, increasing from 33% of the total time in 1995 to 44% in 2011.

Currently, there are very few Rugby Union studies which document the anthropometric and physiological characteristics of youth Rugby Union players, and even fewer regarding psychological attributes. Similarly, very few longitudinal studies recording the changes in these characterics have been published for Rugby Union. Certainly none with a battery of tests as extensive as this study is proposing to implement.

It is crucial that anthropometric, physiological and psychological changes are recorded and analysed throughout youth development to gain a fuller understanding of how athletes progress, ensure that the athletes are properly prepared to cope with the ever changing demands of the game and entry to a professional enviroment.

This study aims to document the physiological, anthropometric and psychological characteristics of different age groups within an Academy pathway at specified time points during the season and compare these data at each time point to determine where any differences can be identified between age groups. This will allow a fuller understanding of how the physical demands affects player's development throughout the season.  It was hypothesized after studying the available literature that at the end of each testing point body mass, fat free mass, maximal strength, lower body power and mental toughness outcome measures would be significantly different when comparing age categories; however, anaerobic fitness and agility are expected to remain similar.

In addition, longitudinal changes in these performance measures within age groups are to be explored with the intention to create an understanding of developments within age groups throughout a competitive season.  It was hypothesized that the greatest change in performance measures would occur in the younger groups due to their stage of development and maturation, alongside their relatively low training history.

# 3. METHODOLOGY

Ethical approval was obtained from the College of Medical, Veterinary and Life Sciences Research Ethics Committee, University of Glasgow. All players were given information sheets outlining the study and their participation (Appendix 8.2). Consent forms were completed by parents/guardians for the players younger than 18 years of age and for all other players.

## 3.1 Experimental Procedure

Elite youth Rugby Union players who were selected for their regional BT Sport Scottish Rugby Academy were tested on an extensive battery of performance measures. The tests and outcome measures included in the battery can be seen in Table 1 below:

| Performance Test | Outcome Measure |
|---|---|
| Anthropometric (BodPod) | Body Mass, Body Fat % (BF (%)) and Fat Free Mass (FFM) |
| Functional Movement (Tuck Jump) | Score out of 10 |
| Lower Body Power | Counter Movement Jump (CMJ) height (cm) |
| Strength 3 Repetition Max (3RM) | Squat, Bench, Chin Absolute and Allometric Scaling |
| Speed | 10m and 30m times (s) and 10m Momentum (kgm/s) |
| Aerobic Fitness (YoYo Intermittent Recovery Test – 1 (YoYo IRT-1)) | Predicted $\dot{V}O_2max$ (ml/kg/min) |
| Anaerobic Fitness (Repeated Sprint) | Mean Time and Percent Decrement |
| Agility | 505 Left and Right Foot Turns (s) |
| Psychological | Sports Mental Toughness Questionnaire (Confidence, Constancy, Control, Total Mental Toughness) |

Table 1: List of tests and associated outcome measures

Each testing point; pre-season (Testing Point 1), mid-season (Testing Point 2) and end of season (Testing Point 3), lasted for two weeks with adequate time between tests to allow for rest, recovery and optimal performance at the next testing point. The testing days were programmed for pre-scheduled training sessions to ensure that the athletes followed their normal schedule, were available and familiar with exercising at the time testing took place. The testing points were scheduled into period of the year where the participants were experiencing 'low' training and match demands. These time points were chosen to ensure maximal testing performances could be achieved. A standardised warm up was used to ensure consistency at each testing point.

## 3.2 Participants

The initial sample size for this study was fifty five players from four different levels within an Academy: U16 (N=18), Age (years) = 15.0±0.0, Body Mass (kg) = 80.9±13.3; U18 (N=16), Age (years) = 16.4±0.6, Body Mass (kg) = 78.5±14.4; BAS2 (N=9), Age (years) = 18.3±0.9, Body Mass (kg) = 93.2±10.2, and BAS3 (N=12), Age (years) = 19.7±1.7, Body Mass (kg) = 96.8±13.2. Data represented as mean ± standard deviation (S.D.) and taken from the initial testing point completed during pre-season 2016/2017. All players were selected into the Academy system and were competing at the highest possible level of their ability, ranging from National Youth club or School teams to playing full professional Rugby Union.

## 3.3 Anthropometric Test Protocol

Body compositions (body mass, BF (%) and FFM) were estimated using the BodPod (Air Displacement Plethysmography (ADP)) which is considered a 'gold standard' in body composition assessment. Height (cm) was obtained using the Leicester Height Stand, although data has not been presented in this study. Participants visited the University of Glasgow to complete this testing. Set protocol was followed, (Appendix 8.3).

## 3.4 Tuck Jump Test Protocol (Functional Movement)

Participants were provided with instructions prior to completing the test. They included a description of the test, the reason why it was being completed and the correct form, in terms of technique, whilst performing the test. A cross was marked on the floor and participants were asked to stand on it before performing 10 seconds worth of tuck jumps. Performances were filmed, for reference and future scoring, using two GoPro cameras. The cameras were placed two metres from the cross on the floor to allow the performance to be filmed in the sagittal and frontal planes to ensure accurate assessment of each jump. During the marking process, in this case the researcher, can rewind, pause and slow down the real time video to allow a more accurate assessment of each tuck jump. Upon completion of reviewing and applying a score to each participant's performance all videos were deleted (Herrington, et al., 2013). This data can then potentially be used to implement interventions where applicable to reduce any risks relating to jumping and landing mechanics.

The reason this test was chosen was due to the kappa measure of agreement = 0.88 (Herrington, et al., 2013). This clearly indicates that marking scores from multiple testers are similar and allow for valid comparisons. See Appendix 8.4 for marking sheet.

## 3.5 Power Testing Protocol

CMJs were performed after a standardised warm using a set protocol. Athletes were asked to place hands on their hips and perform the test. Participants were asked to perform a maximal jump which was repeated three times. The highest jump in centimetres was recorded for analysis. Jumps were measured using the OptoJump system (Microgate, Italy). The equipment was connected via USB to a laptop with the appropriate computer software, OptoJump Next (V1.9.9.0).

## 3.6 Strength Testing Protocols

3RM of Squat, Bench and Chin were used to measure whole body strength. These compound lifts were chosen as the exercises were familiar to all age groups being tested within this study. Self-selected warm up weights, performing high rep ranges, were used as this was a familiar warm up routine for the athletes. Participants were then asked to increase the weight by 5kg or 10kg and perform three repetitions at each weight chosen. Nearing their submaximal lifts athletes were asked to indicate a test lift and ensure one of the experienced coaches were watching the lift to ensure its credibility and record the completed lift weight.

Each exercise had set criteria which had to be met to complete a successful lift. For a 3RM Squat to be valid, participant had to ensure that the top of their thigh was parallel (or lower) to the floor on each lift. As each lift was near maximal, the athletes were offered assistance during the lift in the event of failing their attempt for safety purposes. This technique is taught to all the athletes during their strength and conditioning sessions within the Academy. When completing a 3RM attempt on Bench, athletes were instructed to ensure that they kept their hips in contact with the bench on every lift, decide on a self-selected grip width and finally that the barbell must touch the chest before returning to full extension. To perform a successful attempt requires that at no time during the lift is any form of assistance provided. This test would again be supervised by an experienced coach familiar with the test protocol to ensure correct techniques were implemented for test lifts.

To complete a successful 3RM Chin, athletes were required to perform three repetitions with near full extension of the elbows, then flexion, so their chin was higher than the bar. They were also instructed that each lift had to be completed with virtually no extra movement to gain added momentum and aid the lift. If required, additional weight was added to the athlete (hanging from waist) to ensure an absolute 3RM Chin could be achieved. Maximal lifts (body mass plus additional weight) were recorded and used in later analysis. Similar to selecting Squat as a measure of lower body strength due to its familiarity, Bench and Chin were also exercises used by the participants during their training programmes. Alongside the familiarity, these exercises are commonly used in published literature.

In addition, to absolute testing scores, allometric scaling was used to identify strength when the influence of body mass was removed. This data was calculated using two set equations, one where the lift includes the body mass: performance/body mass$^{-1/3}$. The other equation is for lifts where the body is prone: performance/body mass$^{2/3}$.

## 3.7 Speed Test Protocol

Maximal speed was measured using Witty Speed Gates set at 10m and 30m to record sprint times. The participants followed a standardised warm up of basic dynamic plyometric movements followed by submaximal sprints. They then performed 3x30m maximal effort sprints. The starting position was 0.5m behind the first set of Witty Speed Gates which were set at the lowest stand height so data was comparable throughout the season. Participants were instructed to sprint maximally from the start line though the 10m and 30m gates. They were not given a signal to start, rather they would begin when ready. Each run was separated by a five minute rest period to ensure maximal effort could be produced during each attempt. The fastest times for both 10m and 30m splits were recorded for analysis. 10m Momentum was calculated for analysis purposes using the following equation: kgm/s. All speed testing was carried out on an indoor athletics track to provide the athletes with the best and repeatable conditions to produce absolute maximal velocities.

## 3.8 Aerobic Endurance Test Protocol

The participants performed the YoYo IRT-1 to assess maximal aerobic endurance. Two 20m shuttles were performed followed by a 10 second period of active recovery where the participants are required to walk around a cone 5m behind the start line. The test pace was controlled by an audible signal, where the beep (signal) instructs the participant when the start and end of each shuttle occurs. As the test progresses through the levels, the duration between beeps is reduced and the running pace becomes faster. Each level has a set number of shuttles to be completed. An athlete's test is over when they record two consecutive errors e.g. failing to cross the start line for two consecutive beeps or failing to cross the turn line with their foot. An athlete can elect to finish the test by dropping out through their own volition.

Bangsbro, et al. (2008) documented that the YoYo IRT-1 had a r value of 0.7 when compared to direct measures of $\dot{V}O_2max$. This high reliability value resulted in the decision to use the YoYo IRT-1 to measure aerobic fitness. Predicted $\dot{V}O_2max$ was calculated using the formula IRT-1 Distance (m) x 0.0084 + 36.4 (Bangsbro, et al., 2008). For the purpose of this thesis predicted $\dot{V}O_2max$ has been reported to allow for comparison to current published literature. See Appendix 8.5 for test recording sheet, distance and levels based of predicted $\dot{V}O_2max$. Tests were completed on an indoor 4G artificial pitch.

## 3.9 Anaerobic Endurance Test Protocol

To measure anaerobic endurance participants performed 6x30m sprints interspersed by a 20s active recovery period. A tape line was placed 0.5m behind each set of Witty Speed Gates (Microgate, Italy) to identify starting points. The participants were given a verbal countdown prior to starting each sprint. During the duration of the test, the participants were reminded to sprint maximally on EACH run. All six sprint times were recorded for further analysis. Tests were completed on an indoor 4G artificial pitch. Due to bookings and availability of facilities being made by an external party some testing had to be completed outside during Testing Point 2. However, testing only took place when environmental conditions were dry and calm to ensure no negative environmental influences affected testing. Scores from these testing days were scrutinised to ensure no skewing of data occurred and no trends or deviations were present that would suggest conditions affected the testing.

## 3.10 Agility Test Protocol

The 505 agility test was used to measure the participant's agility. The athletes were positioned at the starting point, which was indicated by a tape line 15m from a turning point which was also identified by a horizontal tape line. They were instructed to accelerate through the set of Witty Speed Gates, which were placed 10m from the starting position, continue to the 15m line then turn and sprint back through the Witty Speed Gates, at which point the timing was complete. Participants completed four attempts separated by a three minute recovery period to allow recovery before the next attempt. They had to complete two attempts turning on the left foot and two on the right. The criteria for a successful attempt given was the athlete had to ensure their whole foot crossed the turning line and made contact with the floor. The quickest times for each turning foot were recorded for future analysis. Testing was carried out on an indoor athletics track.

## 3.11 Psychological Test Protocol

A Sports Mental Toughness Questionnaire (SMTQ) (Sheard, et al., 2009) was completed by participants on the visit to the University of Glasgow when they completed measures for anthropometry. Due to the SMTQ being a valid and reliable measure of mental toughness it was chosen as the questionnaire for this study. Alongside this, the SMTQ does not require license as other mental toughness devices do. The participants were encouraged to answer the questions as truthfully as possible. The SMTQ comprises of 14 items and provides a measure of Total Mental Toughness (MT). Alongside this it also provides a measure of Confidence, Constancy and Control. Statements are scored using a 4-point Likert scale, ranging from (1) not at all true, to (4) very true. Examples of what the athletes had to answer include: Confidence = "I have unshakeable confidence in my ability"; Constancy: "I get distracted easily and lose my concentration"; and Control: "I get anxious by events I did not expect or cannot control" (Sheard, et al., 2009).

## 3.12 Inclusion Criteria

All tests were performed by all participants during the set two week testing points. Tests performed by athletes who were not fully fit were not included in analysis. If a new athlete joined the Academy during the season their data was not included in the next testing point. However, if they were in another BT Sport Scottish Regional Academy prior to testing then data was used in analysis. This only occurred for BAS2 or BAS3 athletes as they would have been part of another regional Academy completing a similar strength and conditioning programme to the younger athletes. If a participant had very poor attendance at the pathway programme during the season but attended testing days their data was not deemed as accurate and was not included in any comparisons. The last situation was discussed and agreed with the strength and conditioning coaches prior to testing and attendance information was regularly provided to allow informed decisions to be made by the lead researcher.

It should be noted that as the testing points took place over a competitive season there will be periods of much higher loading for participants. This was taken into account during the selection of testing dates to minimise the effect of increased workload by ensuring testing points fell during periods of 'low' workloads.

As Rugby Union is a contact sport with multiple collisions and direct confrontation, there is a high injury rate that can occur which would have a direct knock on effect on testing. Unfortunately, this is not under the control of the Lead Researcher. Similarly, school commitments of the youth players may affect their load testing schedule. However, as much testing data were collected as possible during the three set testing periods.

## 3.13 Statistical Analysis

Analyses was carried out using the computer statistical package Minitab V17. Firstly, data were analysed to ensure normality using the Anderson-Darling normality test. Where data was ‘normal’, means and standard deviations were cited – all data were calculated as ‘normal’. Within each testing point, 1-way ANOVAs with Tukey’s post-hoc analysis were performed to compare across levels. The resultant 95% Confidence Intervals identified whether any significant statistical difference existed between the groups – Whole Squad only.

Analysis on the within-cohort longitudinal changes in anthropometric, physiological and psychological performance measures in each cohort were completed using repeated measure ANOVAs. Only longitudinal data for Whole Squad were statistically analysed. Effect sizes were calculated using Cohen’s D (Cohen, 1969). Only large effect sizes are shown in the results: those greater than 0.8 (Sulliven, 2012). All data were calculated by comparing the older groups against the younger groups e.g. BAS3 v U16.

Formal analysis was only completed with cohort sample sizes of four or over. Descriptive statistics are still displayed in the tables for any cohort with a sample size LESS than four.

## 4. RESULTS

The first result section is divided into time point age-group comparisons for Whole Squad. These data are displayed as descriptive statistics in table formats and a written description of formal analysis. Testing data were split for forwards and backs; however these data were only displayed as descriptive statistics in table format. No formal analyses were completed on the positional subcategories due to insufficient cohort sizes. These data are displayed in Tables 2-10 with written formal analysis provided underneath Tables 2, 5 and 8. Statistically significant differences between age groups, are highlighted in each table as letters. If two of the cohorts have the same letter at the end of the descriptive statistics, for each individual outcome measure, they are statistically significantly different from each other. The letters are as follows:

- U18 v U16 = a
- BAS2 v U16 = b
- BAS3 v U16 = c
- BAS2 v U18 = d
- BAS3 v U18 = e
- BAS3 v BAS2 = f

The statistically significant differences can also be found in the written formal analysis, underneath Tables 2, 5 and 8, as 95% Confidence Intervals. Where no statistically significant differences are present, but large effect sizes are, data are provided for the appropriate cohort comparisons.

The second results section presents results from the longitudinal comparisons which comprises of tables containing any changes between each pair of time points, highlighting which outcome measures have statistically significant difference(s) between the two testing points. This is represented in bold in the tables and also written format underneath each table. Following the tables and formal analysis, line graphs are shown, illustrating the change for each outcome measure for all four age groups. Only Whole Squad data were analysed for longitudinal changes due to limitations in cohort sizes, when divided down to positional units.

Combinations from both of these results sections can be found in Appendix 8.6 displayed as bar graphs with significant statistical differences highlighted using letters (age groups comparisons) and symbols (longitudinal comparisons).

# 4.1 Pre-Season Testing Comparisons

## 4.1.1 Whole Squad

*Table 2: Performance outcomes for Whole Squad across the different stages of Academy development during Pre-Season, Testing Point 1.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 16 | 80.9±13.3 c | 10 | 78.3±14.4 e | 8 | 93.2±10.2 | 11 | 96.8±13.2 c e |
| BF (%) | 16 | 16.8±8.7 | 10 | 14.0±4.1 | 8 | 14.9±8.5 | 11 | 12.6±4.1 |
| FFM (kg) | 16 | 66.6±9.2 b c | 10 | 67.0±11.0 e | 8 | 78.8±5.3 b | 11 | 84.3±10.0 c e |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 17 | 6.0±2.0 | 11 | 5.0±1.0 | 6 | 5.0±1.0 | 7 | 5.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 17 | 29.4±3.9 a b c | 11 | 35.7±3.1 a e | 6 | 41.5±5.1 b | 8 | 42.7±6.8 c e |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 18 | 97.1±15.9 b c | 9 | 112.2±21.1 d e | 6 | 153.3±34.4 b d | 7 | 175.0±28.1 c e |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 16 | 417.8±78.2 b c | 9 | 477.0±114.4 d e | 6 | 702.8±153.2 b d | 7 | 806.7±142.4 c e |
| 3RM Bench (kg) | 18 | 64.7±8.0 b c | 11 | 75.9±15.6 d e | 6 | 108.3±5.2 b d | 5 | 121.0±16.7 c e |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 16 | 3.5±0.5 b c | 10 | 4.0±0.4 d e | 6 | 5.3±0.5 b d | 5 | 5.8±0.7 c e |
| 3RM Chin (kg) | 16 | 91.8±10.4 b c | 10 | 94.3±12.2 d e | 6 | 120.0±9.5 b d | 3 | 124.4±5.9 c e |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 16 | 397.9±59.7 a b c | 10 | 404.3±76.3 a d e | 6 | 545.4±49.7 b d | 3 | 589.0±37.1 c e |
| **Speed** | | | | | | | | |
| 10m (s) | 17 | 1.80±0.10 | 11 | 1.73±0.07 | 3 | 1.76±0.06 | 9 | 1.72±0.11 |
| 30m (s) | 17 | 4.46±0.26 c | 11 | 4.25±0.18 | 3 | 4.33±0.15 | 9 | 4.18±0.22 c |
| 10m Momentum (kgm/s) | 15 | 457.2±67.7 c | 9 | 436.4±66.8 e | 3 | 546.9±81.5 | 9 | 549.0±65.9 c e |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 17 | 45.6±3.9 c | 10 | 48.7±4.9 | 6 | 50.1±4.2 | 11 | 51.3±2.8 c |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 17 | 4.90±0.34 | 11 | 4.64±0.16 | 6 | 4.67±0.22 | 5 | 4.67±0.15 |
| RSA % Decrement | 17 | 4.8±2.0 | 11 | 5.0±1.7 | 6 | 5.5±1.2 | 5 | 4.7±1.5 |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 13 | 2.60±0.11 | 9 | 2.45±0.10 | 3 | 2.47±0.08 | 7 | 2.54±0.22 |
| 505 Right Foot (s) | 13 | 2.60±0.16 | 9 | 2.46±0.12 | 3 | 2.47±0.06 | 7 | 2.52±0.14 |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 16 | 18.0±3.0 | 10 | 18.0±1.0 | 6 | 20.0±3.0 | 4 | 21.0±2.0 |
| Constancy (Out of 16) | 16 | 14.0±2.0 | 10 | 14.0±1.0 | 6 | 15.0±2.0 | 4 | 14.0±1.0 |
| Control (Out of 16) | 16 | 12.0±2.0 | 10 | 12.0±2.0 | 6 | 12.0±1.0 | 4 | 12.0±1.0 |
| Total (Out of 56) | 16 | 43.0±7.0 | 10 | 43.0±7.0 | 6 | 47.0±4.0 | 4 | 48.0±3.0 |

Statistically significant differences are illustrated by letters after testing scores: U18 v U16 = a; BAS2 v U16 = b; BAS3 v U16 = c; BAS2 v U18 = d; BAS3 v U18 = e; BAS3 v BAS2 = f.

Table 2 (Page 29) displays the results from the first testing point, at the beginning of the season, for all players within each playing level. Statistically significant differences, shown as 95% CI below, calculated from the ANOVA with Tukey's post hoc analysis and difference of means and non-statistically significant differences but with a large effect size (>0.8) are reported below. Positive effect sizes indicate that the older cohort had a better testing score compared to the younger group, whereas a negative effect size indicates the younger cohort performed better. However, there are some exceptions to this, which indicate the opposite, and they will be highlighted throughout the written formal analysis:

**Anthropometric**

There was also a statistical significant difference seen for body mass (kg) between the oldest Academy level and the two pathway age groups: BAS3 v U16 (2.1, 29.5) and BAS3 v U18 (3.2, 33.8), with mean differences of 15.8kg and 18.5kg respectively. Large effect sizes occurred for the following age group comparisons indicating that the older cohorts are heavier: BAS2 v U16 (1.0) and BAS2 v U18 (1.2).

There were statistically significant differences seen for FFM (kg) following comparisons: BAS3 v U16 and BAS3 v U18 groups ((1.4, 23.0) (6.4, 28.2) respectively), with mean differences of 17.8kg and 17.3kg respectively. Finally, a statistically significant difference was also seen between the BAS2 players and the U16 cohort (1.4, 23.0), with a mean difference of 12.2kg. Comparison between the BAS2 and U18 groups identified no significant statistical difference but a large effect size (1.4) was evident, indicating that the older cohort had more FFM than the younger.

**Functional Movement**

No statistically significant differences occurred; however, a large effect size was evident for the U18 v U16 (-0.9). This indicates that the U18 cohort performed better than the U16 cohort during the Tuck Jump Test as they scored a lower number, giving a negative effect size.

**Lower Body Power**

For CMJ (cm) there were significant statistical differences between the BAS3 v U16 and U18 age groups ((8.0, 18.6) (1.2, 12.6) respectively), with mean differences of 13.3cm and 6.9cm respectively. The BAS2 player's jumps were statistically significantly higher than the U16 players (6.3, 18.0), with a mean difference 12.2cm. Finally, a statistically significant difference occurred for the following comparison: U18 v U16 (1.6, 11.1) with a mean differences of 6.4cm. Despite not being significant, a large effect size (1.4) was present when the BAS2 data were compared to the U18, indicating that the BAS2 cohort jumped higher than the U18 cohort.

**Strength**

3RM Squat performed by the BAS3 players were significantly greater than the U16 and U18 players ((50.7, 105.2) (32.0, 93.6) respectively), with mean differences of 77.9kg and 62.8kg respectively. Similarly, the BAS2 players were also statistically significantly stronger than both the U16 and U18 age groups ((37.5, 85.1) (8.9, 73.3) respectively), with mean differences of 56.3kg and 41.1kg respectively.

When the scores were scaled allometrically, significant statistical differences were calculated, in favour of the older group, between the BAS3 players and the U16 and U18 age groups ((250.4, 527.4) (175.6, 483.8) respectively), with mean differences 388.9AU and 329.7AU respectively. The BAS2 cohort was statistically significantly different from both the U16 and U18 groups ((138.7, 431.4) (64.8, 387.0) respectively, with mean differences of 285.1AU and 225.9AU respectively.

Statistically significant differences for 3RM Bench were evident between the BAS3 v U16 and U18 age groups ((40.6, 71.9) (28.4, 61.8) respectively, with BAS3 players lifting more on average by 56.3kg and 45.1kg respectively. The BAS2 players were lifting statistically significantly more than the U16 and U18 age groups ((29.0, 58.2) (16.8, 48.2) respectively, on average 43.6kg and 32.5kg more respectively. Large effect sizes were calculated for U18 v U16 (0.9) and BAS3 v BAS2 (1.2). These data indicate that the older cohorts in each comparison lifted more than the younger.

Similar statistically significant differences were found when 3RM Bench data were scaled allometrically. BAS3 v U16 (1.6, 3.0) with a mean difference of 2.3AU. BAS3 v U18 (1.0, 2.5) with a mean difference of 1.7AU. BAS2 v U16 (1.1, 2.4) with a mean difference of 1.8AU. Finally, BAS2 v U18 (0.5, 2.0) with a mean difference of 1.3AU. A large effect size (1.1) was seen between the U18 v U16 for 3RM Bench allometric scaling, indicating that when the influence of bodyweight was removed the U18 cohort were still 'stronger' for 3RM Bench compared to the U16 cohort, albeit not statistically significant.

For 3RM Chin significant statistical differences were evident between the BAS3 v U16 and U18 age groups (14.4, 50.7) (11.2, 49.2), with mean differences of 32.6kg and 30.2kg, respectively. BAS2 v U16 (14.3, 41.9), with a mean difference of 28.1kg. Finally, BAS2 v U18 (10.8, 40.6), with a mean difference of 25.7kg.

When 3RM Chin data were scaled allometrically, the BAS3 players were statistically significantly different from the U16 and U18 age groups ((84.5, 297.9) (73.1, 296.4) respectively), with mean differences of 191.2AU and 184.7AU respectively. The BAS2 players were also significantly different from the, U16 and U18 ((66.3, 228.7) (53.5, 228.7) respectively), with mean differences of 147.5AU and 141.1AU respectively. The only non-significant difference with a large effect size was seen between BAS3 v BAS2 (1.0) indicating that the BAS3 cohort were stronger for 3RM chin compared to the BAS2 cohort.

**Speed**

No significant statistical differences or large effect sizes occurred between any comparisons for 10m speed times.

A statistical significant difference for 30m Sprint (s) was evident between BAS3 v U16 (-0.53, -0.04), with a mean difference of -0.28s. Large effect sizes were seen between the following comparisons: U18 v U16 (-1.0) and BAS3 v BAS2 (-0.8). As a lower sprint time indicates a better performance, these negative effect sizes highlight that the older cohorts were faster compared to their younger counterparts, albeit not statistically significantly different.

When Momentum (kgm/s) over 10m was analysed significant statistical differences were seen between for BAS3 v U16 and U18 age groups ((14.1, 169.4) (25.8, 199.4) respectively), with mean differences of 91.8kgm/s and 112.6kgm/s respectively. Despite not being significant, large effect sizes were seen when the BAS2 players were compared to the U16 players (1.2) and also the U18 players (1.5). These data indicate that the older cohort, BAS2, produced more 10m Momentum compared to the younger cohorts.

**Aerobic Fitness**

Statistically significant differences were seen between the BAS3 players and U16 for YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) (1.6, 9.8) respectively, with mean differences of 5.7ml/kg/min respectively, indicating the older group were fitter. Although not significant, large effect size (1.1) was seen between BAS2 v U16 for YoYo IRT-1 predicted $\dot{V}O_2max$, indicating that the BAS2 cohort was aerobically fitter than the U16 cohort.

**Anaerobic Fitness**

When RSA MT was analysed, large effect sizes were seen between all of the groups compared to the U16: U18 (-1.1); BAS2 (-0.8) and BAS3 (-0.9).

As lower sprint times indicate a better performance, these negative effect sizes highlight that the older cohorts were faster compared to their younger counterparts, albeit not statistically significantly different.

**Agility**

No statistically significant differences were seen for 505 Agility Test (s); however large effect sizes were calculated. For the 505L large effect sizes were seen between U18 v U16 (-1.4) and BAS2 v U16 (-1.4). Similarly, the 505R saw large effect sizes between the same groups as above, (-1.0) and (-1.2) respectively. As lower agility times indicate a better performance, these negative effect sizes highlight that the older cohorts were faster compared to their younger counterparts, albeit not statistically significantly different.

**Mental Toughness**

No statistically significant differences were evident for comparisons between any of the developmental levels for any of the sub categories or for Total Mental Toughness. However, large effect sizes were evident for some of the subcategories, as they are positive this indicate that the older cohorts scored higher than the younger cohort they were compared to:

1. Confidence: BAS3 v U16 (1.0); BAS2 v U18 (0.9); BAS3 v U18 (1.6)
2. Total: BAS3 v U18 (1.0)

### 4.1.2 Forwards

*Table 3: Performance outcomes for the forwards only across the different stages of Academy development during Pre-Season Testing Point 1.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 9 | 88.1±10.4 | 4 | 88.5±14.7 | 5 | 98.0±9.1 | 7 | 104.9±6.1 |
| BF (%) | 9 | 20.1±9.2 | 4 | 13.8±3.4 | 5 | 19.3±7.3 | 7 | 13.8±4.2 |
| FFM (kg) | 9 | 69.5±7.7 | 4 | 76.0±9.9 | 5 | 78.6±1.9 | 7 | 90.4±5.1 |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 10 | 6.0±2.0 | 4 | 4.0±1.0 | 4 | 5.0±1.0 | 5 | 5.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 10 | 27.7±1.4 | 4 | 35.1±2.1 | 4 | 40.8±4.5 | 5 | 41.4±8.0 |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 10 | 95.2±16.6 | 3 | 116.7±40.4 | 5 | 150.0±37.4 | 5 | 178.0±33.5 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 9 | 416.4±81.5 | 3 | 519.0±212.0 | 5 | 689.5±167.3 | 5 | 836.9±161.8 |
| 3RM Bench (kg) | 10 | 65.0±6.7 | 5 | 85.5±17.4 | 4 | 108.8±6.3 | 3 | 128.3±16.7 |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 9 | 3.3±0.5 | 4 | 4.1±0.6 | 4 | 5.2±0.6 | 3 | 5.7±0.7 |
| 3RM Chin (kg) | 9 | 95.2±3.7 | 4 | 102.8±13.4 | 4 | 121.1±11.4 | 3 | 124.4±5.9 |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 9 | 423.4±30.7 | 4 | 459.5±84.7 | 4 | 556.3±54.2 | 3 | 589.0±37.1 |
| **Speed** | | | | | | | | |
| 10m (s) | 10 | 1.83±0.10 | 4 | 1.73±0.08 | 2 | 1.78±0.08 | 5 | 1.76±0.08 |
| 30m (s) | 10 | 4.55±0.26 | 4 | 4.23±0.22 | 2 | 4.40±0.13 | 5 | 4.22±0.21 |
| 10m Momentum (kgm/s) | 9 | 485.1±51.2 | 3 | 484.8±72.1 | 2 | 588.2±55.1 | 5 | 596.4±33.8 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 10 | 43.3±2.0 | 4 | 50.5±5.1 | 4 | 48.6±4.4 | 7 | 50.4±2.8 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 10 | 5.04±0.35 | 4 | 4.68±0.22 | 4 | 4.74±0.22 | 3 | 4.69±0.21 |
| RSA % Decrement | 10 | 5.5±1.7 | 4 | 4.5±1.6 | 4 | 5.7±1.4 | 3 | 5.2±1.8 |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 9 | 2.64±0.11 | 4 | 2.46±0.14 | 2 | 2.45±0.10 | 5 | 2.57±0.26 |
| 505 Right Foot (s) | 9 | 2.66±0.16 | 4 | 2.49±0.16 | 2 | 2.45±0.04 | 5 | 2.54±0.16 |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 9 | 18.0±3.0 | 6 | 18.0±1.0 | 3 | 20.0±2.0 | - | - |
| Constancy (Out of 16) | 9 | 14.0±2.0 | 6 | 14.0±2.0 | 3 | 14.0±2.0 | - | - |
| Control (Out of 16) | 9 | 12.0±2.0 | 6 | 12.0±2.0 | 3 | 12.0±1.0 | - | - |
| Total (Out of 56) | 9 | 42.0±8.0 | 6 | 45.0±4.0 | 3 | 46.0±3.0 | - | - |

### 4.1.3 Backs

*Table 4: Performance outcomes for the backs only across the different stages of Academy development during Pre-Season, Testing Point 1.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 7 | 71.8±11.3 | 6 | 71.4±10.2 | 3 | 85.3±6.6 | 4 | 82.4±8.7 |
| BF (%) | 7 | 12.4±6.0 | 6 | 14.2±4.8 | 3 | 7.5±3.9 | 4 | 10.4±3.2 |
| FFM (kg) | 7 | 62.8±10.2 | 6 | 61.2±7.1 | 3 | 79.1±9.6 | 4 | 73.8±7.0 |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 7 | 5.0±1.0 | 7 | 5.0±1.0 | 2 | 4.0±1.0 | 2 | 5.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 7 | 31.8±5.1 | 7 | 36.1±3.7 | 2 | 43.1±7.9 | 3 | 44.8±4.6 |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 8 | 99.4±15.7 | 6 | 110.0±6.3 | - | - | 2 | 167.5±10.6 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 7 | 419.5±80.1 | 6 | 455.8±36.7 | - | - | 2 | 731.0±29.1 |
| 3RM Bench (kg) | 8 | 64.4±9.8 | 6 | 67.4±8.6 | 2 | 107.5±3.5 | 2 | 110.0±14.1 |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 7 | 3.7±0.5 | 6 | 3.9±0.3 | 2 | 5.5±0.5 | 2 | 5.8±1.0 |
| 3RM Chin (kg) | 7 | 87.5±14.6 | 6 | 88.5±8.0 | 2 | 117.8±7.1 | - | - |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 7 | 365.0±73.7 | 6 | 367.5±45.9 | 2 | 523.5±45.9 | - | - |
| **Speed** | | | | | | | | |
| 10m (s) | 7 | 1.75±0.08 | 7 | 1.73±0.07 | - | - | 4 | 1.69±0.14 |
| 30m (s) | 7 | 4.34±0.22 | 7 | 4.26±0.17 | - | - | 4 | 4.13±0.24 |
| 10m Momentum (kgm/s) | 6 | 415.4±71.8 | 6 | 412.2±54.4 | - | - | 4 | 489.7±40.5 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 7 | 48.9±3.7 | 6 | 47.5±4.7 | 2 | 53.0±1.2 | 4 | 52.9±2.1 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 7 | 4.71±0.22 | 7 | 4.61±0.12 | 2 | 4.53±0.17 | 2 | 4.65±0.04 |
| RSA % Decrement | 7 | 3.9±2.0 | 7 | 5.3±1.9 | 2 | 5.0±1.0 | 2 | 4.0±0.3 |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 4 | 2.51±0.06 | 5 | 2.50±0.00 | - | - | 2 | 2.45±0.08 |
| 505 Right Foot (s) | 4 | 2.49±0.03 | 5 | 2.44±0.09 | - | - | 2 | 2.47±0.11 |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 7 | 19.0±3.0 | 4 | 18.0±2.0 | 3 | 20.0±5.0 | 3 | 22.0±1.0 |
| Constancy (Out of 16) | 7 | 14.0±2.0 | 4 | 14.0±1.0 | 3 | 15.0±1.0 | 3 | 14.0±1.0 |
| Control (Out of 16) | 7 | 12.0±2.0 | 4 | 12.0±2.0 | 3 | 12.0±2.0 | 3 | 13.0±1.0 |
| Total (Out of 56) | 7 | 46.0±6.0 | 4 | 40.0±9.0 | 3 | 48.0±6.0 | 3 | 49.0±3.0 |

## 4.2 Mid-Season Testing Comparisons

### 4.2.1 Whole Squad

*Table 5: Performance outcomes for the Whole Squad across the different stages of Academy development at the mid-point of a competitive season, Testing Point 2.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 18 | 84.2±15.2 c | 13 | 79.3±12.8 d e | 8 | 97.0±11.1 d | 8 | 101.2±13.6 c e |
| BF (%) | 17 | 17.9±8.0 | 12 | 15.7±4.7 | 6 | 16.3±8.0 | 7 | 12.8±4.0 |
| FFM (kg) | 17 | 66.9±8.7 b c | 12 | 66.4±9.7 d e | 6 | 80.1±5.8 b d | 7 | 86.1±11.1 c e |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 14 | 4.0±1.0 | 10 | 4.0±1.0 | 5 | 5.0±1.0 | 7 | 5.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 15 | 32.2±4.6 a b c | 11 | 39.8±6.5 a | 8 | 42.3±7.2 b | 8 | 44.0±8.1 c |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 10 | 107.5±17.0 b c | 11 | 124.4±21.2 b d | 5 | 162.0±22.0 b d | 4 | 171.3±24.6 c e |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 10 | 467.1±85.0 b c | 11 | 533.4±106.6 b d | 5 | 733.7±109.5 b d | 4 | 795.4±155.7 c e |
| 3RM Bench (kg) | 13 | 70.1±9.1 b c | 12 | 83.0±11.5 b d | 7 | 114.3±12.1 b d | 6 | 133.3±20.7 c e |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 13 | 3.8±0.4 a b c | 11 | 4.4±0.4 b d | 6 | 5.4±0.4 b d | 6 | 5.3±0.6 c e |
| 3RM Chin (kg) | 12 | 95.7±10.5 c | 10 | 96.3±15.3 e | 6 | 111.7±11.3 | 6 | 119.7±13.8 c e |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 12 | 417.5±63.1 c | 10 | 414.0±83.0 e | 6 | 514.6±68.3 | 6 | 553.8±82.9 c e |
| **Speed** | | | | | | | | |
| 10m (s) | 14 | 1.79±0.22 | 12 | 1.75±0.08 | 7 | 1.77±0.06 | 8 | 1.76±0.09 |
| 30m (s) | 13 | 4.49±0.34 a | 12 | 4.22±0.20 a | 7 | 4.26±0.18 | 8 | 4.23±0.17 |
| 10m Momentum (kgm/s) | 14 | 466.2±73.8 c | 11 | 463.2±76.1 e | 7 | 530.2±73.5 | 8 | 575.1±71.2 c e |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 16 | 46.8±4.3 | 12 | 48.9±4.7 | 7 | 50.4±3.0 | 5 | 49.2±2.9 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 14 | 4.96±0.48 | 12 | 4.68±0.28 | 4 | 4.69±0.18 | 4 | 4.83±0.02 |
| RSA % Decrement | 14 | 5.6±1.7 | 12 | 6.2±2.0 | 4 | 6.4±0.6 | 4 | 5.0±1.2 |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 11 | 2.66±0.17 c | 6 | 2.49±0.17 | 4 | 2.47±0.10 | 7 | 2.45±0.13 c |
| 505 Right Foot (s) | 11 | 2.63±0.13 | 6 | 2.50±0.26 | 4 | 2.49±0.08 | 7 | 2.43±0.06 |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 16 | 18.0±3.0 c | 12 | 19.0±2.0 | 6 | 19.0±3.0 | 7 | 21.0±1.0 c |
| Constancy (Out of 16) | 16 | 10.0±1.0 | 12 | 10.0±1.0 | 6 | 11.0±1.0 | 7 | 10.0±1.0 |
| Control (Out of 16) | 16 | 13.0±2.0 | 12 | 13.0±1.0 | 6 | 12.0±1.0 | 7 | 12.0±2.0 |
| Total (Out of 56) | 16 | 40.0±4.0 | 12 | 42.0±3.0 | 6 | 41.0±4.0 | 7 | 43.0±3.0 |

Statistically significant differences are illustrated by letters after testing scores: U18 v U16 = a; BAS2 v U16 = b; BAS3 v U16 = c; BAS2 v U18 = d; BAS3 v U18 = e; BAS3 v BAS2 = f.

Table 5 (Page 37) displays the results from the *second* testing point, at the middle of the season, for all the players within each playing level. Statistically significant differences, shown as 95% CI below, calculated from the ANOVA with Tukey's post hoc analysis and difference of means and non-statistically significant differences but with a large effect size (>0.8) are reported below. Positive effect sizes indicate that the older cohort had a better testing score compared to the younger group, whereas a negative effect size indicates the younger cohort performed better. However, there are some exceptions to this, which indicate the opposite, and they will be highlighted throughout the written formal analysis:

**Anthropometric**

When body mass (kg) was analysed, significant statistical differences were evident between the BAS3 v U16 players and BAS3 v U18 players ((1.5, 32.5) (5.5, 38.3) respectively), with the BAS3 group being heavier, on average by, 17.0kg and 21.9kg respectively. A statistical significant difference was also seen between BAS2 v U18 (1.3, 34.1), with a difference of mean of 17.7kg. Despite not being statistically different, a large effect size was calculated, BAS2 v U16 (1.0) indicating that the BAS2 cohort was heavier than the U16 cohort.

Statistically significant differences were evident for FFM (kg) between the BAS3 players v U16 and U18 groups ((8.2, 30.2) (8.1, 31.4) respectively), with mean differences of 19.2kg and 19.7kg respectively. Statistically significant differences were also seen between the BAS2 players v the U16 and U18 counterparts ((1.5, 24.8) (1.4, 25.9) respectively), with mean differences of 13.2kg and 13.7kg respectively.

**Functional Movement**

No significant statistical differences were calculated but a large effect size was seen for BAS3 v U18 (-0.8). This indicates the U18 cohort performed the Tuck Jump Test more efficiently than their older counterparts.

**Lower Body Power**

At Testing Point 2, all the older groups jumped significantly higher during the CMJ test (cm) compared to the U16 group. BAS3 v U16 (4.3, 19.3), with a mean difference of 11.8cm. BAS2 v U16 (2.6, 17.6), with a mean difference of 10.1cm. Finally, U18 v U16 (0.9, 14.5), with a mean difference of 7.7cm.

**Strength**

As with Testing Point 1, statistically significant differences for 3RM Squat (kg) scores were evident, at Testing Point 2, between the BAS3 v U16 and U18 groups ((30.6, 96.9) (14.2, 79.6) respectively), with mean differences of 63.8kg and 46.9kg respectively. Significant statistical differences were also present between the BAS2 v U16 and U18 groups ((23.8, 85.2) (7.4, 67.8) respectively), with mean differences of 54.5kg and 37.6kg respectively. A large effect sizes was also seen, U18 v U16 (0.9) indicating that the U18 cohort lifted more than the U16 cohort for 3RM Squat.

However, when allometrically scaled, statistically significant differences were evident between the BAS3 v U16 and U18 players ((154.2, 502.5) (90.1, 433.9) respectively, with mean differences of 328.3AU and 262.0AU respectively. Statistically significant differences also occurred between the BAS2 v U16 and U18 groups ((105.4, 427.8) (41.5, 359.0) respectively), with mean differences of 266.6AU and 200.3AU respectively.

Statistical analysis on 3RM Bench (kg) testing scores identified significant statistical differences between the BAS3 v U16 and U18 players ((26.4, 60.1) (13.3, 47.5) respectively), with the BAS3 group lifting more on average, 43.3kg and 30.4kg respectively. Statistically significant differences were also evident between the BAS2 players v U16 and U18 players ((28.2, 60.3) (15.1, 47.6) respectively), with mean differences of 44.2kg and 31.3kg respectively. A large effect size was evident, U18 v U16 (1.3). This indicates that the U18 cohort lifted more, albeit not statistically significant, than the U16 cohort for 3RM Bench.

When the 3RM Bench scores were scaled allometrically, statistically significant differences were evident between almost all of the comparisons: U18 v U16 (0.1, 1.2), with a mean difference of 0.6AU; BAS2 v U16 (1.0, 2.3), with a mean difference of 1.6AU; BAS3 v U16 (0.9, 2.2), with a mean difference of 1.5AU; BAS2 v U18 (0.4, 1.6), with a mean difference of 1.0AU and BAS3 v U18 (0.3, 1.5), with a difference of means 0.9AU.

Statistically significant differences were evident for 3RM Chin (kg). The BAS3 cohort was statistically significantly stronger than both the U16 and U18 groups ((6.6, 41.4) (5.4, 41.4) respectively), with mean differences of 24.0kg and 23.4kg respectively. Large effect sizes were present for the following comparisons indicating that the BAS2 cohort lifted more for 3RM Chin compared their younger counterparts: BAS2 v U16 (1.5) and BAS2 v U18 (1.2).

When scaled allometrically, statistically significant differences were present between the BAS3 v U16 and U18 age groups ((35.9, 236.8) (36.1, 243.6) respectively). Although not significant, large effect sizes between the BAS2 cohort and both the U16 (1.5) and U18 (1.3) counterparts were evident, indicating when 3RM Chin data were scaled allometrically removing the influence of bodyweight, the BAS2 cohort were stronger.

**<u>Speed</u>**

Statistically significant differences were evident for 30m sprint times (s) for U18 v U16 (-0.54, -0.01), with a mean difference of -0.27s. Large effect sizes were present between the U16 cohort compared to the BAS2 and BAS3 groups ((-0.9) (-1.0) respectively). A negative effect size indicates that the older cohorts had faster 30m sprint times compared to the U16 group.

When analysing 10m Momentum (kgm/s) statistically significant differences were present between the BAS3 v U16 and U18 groups ((20.7, 197.2) (19.5, 204.5) respectively, with mean differences of 109.0kgm/s and 112.0kgm/s respectively. A large effect size (0.9) was calculated between the BAS2 cohort when compared to both the U16 and U18 age groups.

**Aerobic Fitness**

Despite there being no statistically significant differences between the groups for aerobic fitness, large effect sizes were evident between BAS2 v U16 for YoYo Predicted $\dot{V}O_2max$ (1.0), indicating that the BAS2 cohort were aerobically fitter than the U16 cohort.

**Anaerobic Fitness**

No statistically significant differences were evident between the groups for both outcome measures, there were large effect sizes calculated across the cohort comparisons:

1. RSA MT: BAS3 v U18 (1.0) and BAS3 v BAS2 (1.3).
2. RSA %D: BAS3 v BAS2 (-1.5).

For both anaerobic fitness outcome measures, the negative effect sizes indicate that older cohorts were faster and had a lower RSA %D compared to their younger counterparts. In contrast to this, a positive effect size indicates the opposite result.

**Agility**

A statistical significant difference was evident between the BAS3 and U16 players when the 505 agility test (s) with a left foot turn was analysed (-0.42, -0.01), with a mean difference of -0.21s. For 505L large effect sizes were seen between the U16 v both the U18 (-1.0) and BAS2 (-1.4) groups. Large effect sizes for 505R were seen between the U16 v the BAS2 and BAS3 age groups ((-1.3) (-2.0) respectively). These negative effect sizes highlight quicker agility times for older cohort groups.

**Mental Toughness**

A statistically significant difference was calculated between BAS3 v U16 (0.0, 6.0), with a mean difference of 3.0AU for Confidence.

For the comparisons which were not statistically significant some calculated large effect sizes:

1. Confidence: BAS3 v U18 (1.3); BAS3 v BAS2 (1.0).
2. Constancy: BAS2 v U18 (0.9).
3. Control: BAS2 v U18 (-0.9).

All positive effect sizes highlight the older cohort when compared to the younger cohort scored higher. A negative effect size for control highlights that the BAS2 cohort have less control compared to the U18 cohort. This is in contrast to the other large positive effect sizes where older cohort scored higher compared to the younger group.

### 4.2.2 Forwards

*Table 6: Performance outcomes for the forwards only across the different stages of Academy development at the mid-point of a competitive season, Testing Point 2.*

| **Output Measures** | **U16** | | **U18** | | **Stage 2** | | **Stage 3** | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 10 | 92.8±12.8 | 5 | 88.5±13.7 | 6 | 100.7±9.7 | 6 | 107.3±6.6 |
| BF (%) | 9 | 20.9±8.2 | 4 | 18.7±2.7 | 4 | 20.9±3.1 | 5 | 12.7±4.6 |
| FFM (kg) | 9 | 70.8±6.6 | 4 | 73.2±11.5 | 4 | 80.2±2.5 | 5 | 91.2±4.4 |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 9 | 5.0±1.0 | 4 | 5.0±1.0 | 3 | 4.0±2.0 | 5 | 5.0±0.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 9 | 30.1±3.6 | 4 | 39.6±7.0 | 6 | 40.9±4.5 | 6 | 41.7±6.8 |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 6 | 105.2±10.8 | 4 | 126.3±36.4 | 4 | 165.0±24.2 | 4 | 175.0±17.3 |
| Squat Allometric Scaling ($Perf/BW^{-1/3}$) | 6 | 471.4±57.5 | 4 | 557.8±180.31 | 4 | 755.2±113.6 | 4 | 827.9±92.1 |
| 3RM Bench (kg) | 8 | 71.0±8.2 | 5 | 88.0±13.0 | 5 | 119.0±6.5 | 4 | 125.0±12.9 |
| Bench Allometric Scaling ($Perf/BW^{2/3}$) | 8 | 3.6±0.4 | 5 | 4.4±0.6 | 5 | 5.5±0.3 | 4 | 5.5±0.5 |
| 3RM Chin (kg) | 8 | 98.1±5.1 | 4 | 104.3±16.6 | 5 | 115.9±4.9 | 4 | 125.6±10.9 |
| Chin Allometric Scaling ($Perf/BW^{-1/3}$) | 8 | 437.8±36.1 | 4 | 459.8±93.8 | 5 | 539.4±35.0 | 4 | 595.5±47.2 |
| **Speed** | | | | | | | | |
| 10m (s) | 9 | 1.88±0.13 | 4 | 1.75±0.07 | 5 | 1.78±0.07 | 6 | 1.77±0.07 |
| 30m (s) | 8 | 4.62±0.37 | 4 | 4.24±0.22 | 5 | 4.32±0.18 | 6 | 4.26±0.16 |
| 10m Momentum (kgm/s) | 9 | 498.2±51.1 | 4 | 520.8±85.0 | 5 | 564.7±53.5 | 6 | 607.0±44.7 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 10 | 44.4±3.5 | 5 | 47.7±5.4 | 5 | 49.4±2.8 | 4 | 48.3±2.4 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 9 | 5.14±0.51 | 4 | 4.78±0.32 | 3 | 4.66±0.21 | 2 | 4.84±0.00 |
| RSA % Decrement | 9 | 6.1±1.9 | 4 | 7.2±2.6 | 3 | 6.4±0.7 | 2 | 5.8±1.3 |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 8 | 2.71±0.17 | - | - | 3 | 2.48±0.12 | 5 | 2.48±0.13 |
| 505 Right Foot (s) | 8 | 2.66±0.14 | - | - | 3 | 2.48±0.10 | 5 | 2.43±0.05 |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 8 | 18.0±2.0 | 4 | 19.0±1.0 | 4 | 19.0±1.0 | 5 | 20.0±1.0 |
| Constancy (Out of 16) | 8 | 10.0±1.0 | 4 | 10.0±2.0 | 4 | 11.0±1.0 | 5 | 10.0±1.0 |
| Control (Out of 16) | 8 | 13.0±2.0 | 4 | 13.0±2.0 | 4 | 12.0±1.0 | 5 | 11.0±1.0 |
| Total (Out of 56) | 8 | 41.0±4.0 | 4 | 42.0±4.0 | 4 | 41.0±2.0 | 5 | 42.0±2.0 |

### 4.2.3 Backs

*Table 7: Performance outcomes for the backs only across the different stages of Academy development at the mid-point of a competitive season, Testing Point 2.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 8 | 73.5±10.6 | 8 | 73.5±8.6 | 2 | 85.8±7.5 | 4 | 83.3±8.0 |
| BF (%) | 8 | 14.6±6.8 | 8 | 14.2±4.9 | 2 | 7.1±6.1 | 2 | 13.1±3.4 |
| FFM (kg) | 8 | 62.6±9.2 | 8 | 63.0±7.2 | 2 | 79.9±12.2 | 2 | 71.7±8.6 |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 5 | 3.0±1.0 | 6 | 4.0±2.0 | 2 | 5.0±0.0 | 2 | 4.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 6 | 35.3±4.5 | 7 | 40.0±6.7 | 2 | 46.0±14.7 | 2 | 50.8±10.5 |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 4 | 110.0±25.3 | 7 | 123.3±9.2 | - | - | 3 | 151.7±17.6 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 4 | 460.7±126.9 | 7 | 519.5±45.8 | - | - | 3 | 655.0±85.8 |
| 3RM Bench (kg) | 5 | 68.6±11.4 | 7 | 79.4±9.6 | 2 | 102.5±17.7 | 4 | 103.8±21.4 |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 5 | 4.0±0.3 | 6 | 4.4±0.4 | - | - | 4 | 5.5±1.2 |
| 3RM Chin (kg) | 4 | 20.6±5.2 | 6 | 16.2±10.0 | 2 | 20.0±14.1 | 4 | 30.6±6.6 |
| 3RM Chin (kg) | 4 | 90.8±17.1 | 6 | 90.9±13.1 | - | - | 4 | 131.5±39.5 |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 4 | 376.9±90.8 | 6 | 383.5±65.9 | - | - | 4 | 498.2±58.3 |
| **Speed** | | | | | | | | |
| 10m (s) | 5 | 1.75±0.08 | 8 | 1.76±0.09 | 2 | 1.74±0.06 | 4 | 1.67±0.11 |
| 30m (s) | 5 | 4.29±0.16 | 8 | 4.21±0.20 | 2 | 4.12±0.11 | 4 | 4.05±0.20 |
| 10m Momentum (kgm/s) | 5 | 408.6±77.6 | 7 | 430.3±50.7 | 2 | 494.0±59.0 | 4 | 500.6±36.8 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 6 | 50.8±1.6 | 7 | 49.8±4.3 | 2 | 52.9±2.4 | - | - |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 5 | 4.63±0.20 | 8 | 4.63±0.27 | - | - | 2 | 4.81±0.00 |
| RSA % Decrement | 5 | 4.8±0.8 | 8 | 5.6±1.6 | - | - | 2 | 4.2±0.5 |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 3 | 2.55±0.09 | 5 | 2.52±0.17 | - | - | 2 | 2.36±0.06 |
| 505 Right Foot (s) | 2 | 2.52±0.02 | 6 | 2.53±0.25 | - | - | 2 | 2.45±0.12 |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 8 | 17.0±4.0 | 8 | 19.0±2.0 | 2 | 19.0±6.0 | 2 | 22.0±1.0 |
| Constancy (Out of 16) | 8 | 10.0±1.0 | 8 | 10.0±1.0 | 2 | 12.0±1.0 | 2 | 10.0±1.0 |
| Control (Out of 16) | 8 | 13.0±1.0 | 8 | 13.0±1.0 | 2 | 12.0±2.0 | 2 | 14.0±2.0 |
| Total (Out of 56) | 8 | 40.0±5.0 | 8 | 42.0±3.0 | 2 | 42.0±8.0 | 2 | 46.0±2.0 |

## 4.3 End of Season Testing Comparisons

### 4.3.1 Whole Squad

*Table 8: Performance outcomes for the Whole Squad across the different stages of Academy development at the end of a competitive season, Testing Point 3.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 14 | 87.4±16.9 | 8 | 84.9±14.3 | 7 | 93.8±11.2 | 9 | 99.9±13.6 |
| BF (%) | 14 | 20.6±10.1 | 8 | 17.4±4.5 | 7 | 17.6±7.4 | 9 | 14.2±4.5 |
| FFM (kg) | 14 | 68.2±8.6 c | 8 | 69.6±8.0 | 7 | 76.7±4.2 | 9 | 85.5±11.0 c |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 12 | 6.0±1.0 a | 7 | 4.0±1.0 a | 5 | 5.0±1.0 | 2 | 4.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 12 | 32.2±5.5 b c | 6 | 36.2±3.6 e | 6 | 40.6±3.7 b f | 4 | 51.0±8.9 c e f |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 13 | 110.4±19.2 c | 8 | 121.3±20.1 e | - | - | 8 | 176.8±22.9 c e |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 13 | 491.3±103.5 c | 6 | 523.9±118.6 e | - | - | 8 | 828.7±131.1 c e |
| 3RM Bench (kg) | 14 | 74.1±8.7 c | 8 | 78.8±6.4 e | 3 | 118.3±2.9 | 7 | 129.9±21.0 c |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 14 | 3.8±0.4 c | 6 | 4.2±0.2 e | 3 | 5.7±0.3 | 7 | 6.0±0.6 c |
| 3RM Chin (kg) | 11 | 101.0±10.9 c | 6 | 100.4±12.1 e | 3 | 111.3±7.8 | 4 | 143.9±6.1 c e |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 11 | 443.1±76.2 c | 6 | 438.2±75.1 e | 3 | 507.7±53.9 | 4 | 682.0±35.4 c e |
| **Speed** | | | | | | | | |
| 10m (s) | 12 | 1.85±0.12 | 6 | 1.76±0.05 | 6 | 1.80±0.10 | 4 | 1.71±0.08 |
| 30m (s) | 12 | 4.56±0.33 | 6 | 4.33±0.15 | 4 | 4.23±0.13 | 2 | 4.15±0.15 |
| 10m Momentum (kgm/s) | 12 | 468.7±76.4 | 6 | 467.9±69.2 | 5 | 535.8±67.8 | 4 | 573.7±77.6 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 8 | 45.6±4.3 | 4 | 49.6±4.4 | 4 | 47.5±2.0 | 4 | 49.8±2.7 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 12 | 4.96±0.50 | 6 | 4.60±0.24 | 4 | 4.76±0.34 | - | - |
| RSA % Decrement | 12 | 4.7±2.0 | 6 | 5.1±2.0 | 4 | 3.7±1.9 | - | - |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 11 | 2.53±0.12 a | 5 | 2.32±0.13 a | 4 | 2.41±0.08 | - | - |
| 505 Right Foot (s) | 11 | 2.47±0.14 | 5 | 2.35±0.11 | 4 | 2.41±0.13 | - | - |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 12 | 19.0±1.0 | 8 | 20.0±2.0 | 5 | 20.0±3.0 | 6 | 19.0±3.0 |
| Constancy (Out of 16) | 12 | 11.0±1.0 | 8 | 10.0±1.0 | 5 | 10.0±1.0 | 6 | 10.0±2.0 |
| Control (Out of 16) | 12 | 12.0±2.0 | 8 | 12.0±2.0 | 5 | 12.0±2.0 | 6 | 11.0±2.0 |
| Total (Out of 56) | 12 | 41.0±3.0 | 8 | 42.0±3.0 | 5 | 42.0±5.0 | 6 | 40.0±6.0 |

Statistically significant differences are illustrated by letters after testing scores: U18 v U16 = a; BAS2 v U16 = b; BAS3 v U16 = c; BAS2 v U18 = d; BAS3 v U18 = e; BAS3 v BAS2 = f.

Table 8 (Page 45) displays the results from the final testing point, at the end of the season, for all players within each playing level. Statistically significant differences at a 95% CI, calculated from the ANOVA with Tukey's post hoc analysis and difference of means and non-statistically significant differences but with a large effect size (>0.8) are reported in the formal analysis. Positive effect sizes indicate that the older cohort had a better testing score compared with the younger group, whereas a negative effect size indicates the younger cohort performed better. However, there are some exceptions to this, which indicate the opposite, and they will be highlighted throughout the written formal analysis:

**Anthropometric**

From analysis of anthropometric data it was evident that there was no statistically significant differences for any of the outcome measure apart from FFM (kg). Significant statistical differences were evident between BAS3 v U16 (7.4, 27.2), with a mean difference of 17.3kg, BAS3 v U18 (4.6, 27.1), with a mean difference of 15.8kg.

Large effect sizes were evident:

1. Body Mass: BAS3 v U16 (0.8) and BAS3 v U18 (1.1).
2. BF (%): BAS3 v U16 (-0.9).
3. FFM: BAS2 v U16 (1.3); BAS2 v U18 (1.2) and BAS3 v BAS2 (1.2).

Positive large effect sizes indicates that the older cohort were heavier or had more FFM than the younger cohort they were compared to. For BF (%) the large negative effect size indicates that the BAS3 cohort had a lower calculated BF (%) compared to the U16 cohort.

**Functional Movement**

A statistically significant difference was present between one comparison: U18 v U16 (-3.0, 0.0), with a mean difference of 2.0AU. However, large effect sizes were evident between the following comparisons: BAS2 v U16 (-0.8); BAS3 v U16 (-1.6); BAS2 v U18 (0.8).

A large negative effect size calculated for Tuck Jump Test scores indicates a better performed test by the older cohort compared to the younger group.

**Lower Body Power**

Analysis of CMJ (cm) scores identified statistically significant differences between the U16 cohort compared to the BAS2 and BAS3 (0.9, 15.8) (10.2, 27.4), with mean differences of 8.4cm and 18.8cm respectively, in favour of the older groups compared to the U16 cohort. In addition, significant statistical differences were evident between BAS3 v U18 (5.2, 24.4), with a mean difference of 14.8cm and BAS3 v BAS2 (0.9, 20.1), with a mean difference of 10.5cm. Albeit not significant, a large effect size was seen: U18 v U16 (0.9) indicating that the U18 cohort jumped higher than the U16 cohort.

**Strength**

Analysis of lower body strength measured by 3RM Squat (kg) was only able to be completed with the U16, U18 and BAS3 cohorts as no BAS2 players completed a 3RM Squat attempt.

Statistically significant differences were seen between the BAS3 and both younger groups: U16 (43.5, 89.2) and U18 (30.0, 81.0), with BAS3 players lifting on average 66.4kg more than the U16 cohort and 55.5kg more than the U18 cohort.

Allometric scaling of 3RM Squat data identified significant statistical differences between the BAS3 v U16 and U18 cohorts: U16 (20.8, 466.8), with a mean difference of 337.4AU and with a mean difference of 304.8AU, all in favour of the BAS3 cohort.

Analysis of 3RM Bench (kg) data were carried out for all groups. Statistically significant differences were seen between BAS2 v U16 (23.7, 64.8), with a mean difference of 44.3kg; BAS3 v U16 (40.9, 70.8), with a mean difference of 55.9kg; BAS2 v U18 (17.7, 61.5), with a mean difference of 39.6kg and BAS3 v U18 (34.5, 67.9), with a mean difference of 51.2kg. Although not significant a large effect size was seen, BAS3 v BAS2 (1.0), indicating that the BAS3 cohort lifted more than the BAS2 cohort.

When scaled allometrically, significant statistical differences were seen between: BAS2 v U16 (1.2, 2.7), with a mean difference of 1.9AU; BAS3 v U16 (1.6, 2.7), with a mean difference of 2.2AU; U18 and BAS2 (0.6, 2.3), with a mean difference of 1.5AU and BAS3 v U18 (1.1, 2.4), with a mean difference of 1.8AU. A large effect size was seen, U18 v U16 (1.4) suggesting the U18 cohort were stronger compared to the U16 cohort, when 3RM Bench scaled allometrically.

Data for 3RM Chin showed significant statistical differences were evident between: BAS3 v U16 (25.9, 59.8), with a mean difference of 42.9kg; U18 and BAS3 (24.8, 62.2), with a mean difference of 43.5kg; BAS2 and BAS3 (10.4, 54.8), with a mean difference of 32.6kg. Finally, although not significant, large effect sizes (1.1) were seen between the BAS2 v U16 and U18, indicating that the BAS2 were stronger for 3RM chin compared to the younger cohorts.

Finally, when scaled allometrically statistically significant differences were evident between: BAS3 v U16 (125.8, 352.1), with a mean difference of 238.9AU; BAS3 v U18 (118.7, 368.9), with a mean difference of 243.8AU and BAS3 v BAS2 (26.3, 322.3), with a mean difference of 174.3AU. A large effect size was seen between the following comparisons: BAS2 v U16 (1.0) and BAS2 v U18 (1.1). These data indicate that the BAS2 cohort were stronger for 3RM Chin when scaled allometrically compared to the younger cohorts.

**Speed**

For all of the speed outcome measures there were no statistically significant differences. For 10m sprint large effect sizes were seen between: U18 v U16 (-1.0); BAS3 v U16 (-1.4) and BAS3 v BAS2 (-0.9).

Large effect sizes were calculated for 30m times between the U16 and all other groups: U18 (-1.0); BAS2 (-1.4) and BAS3 (-1.7). A large effect size was seen for 30m times between the BAS3 v U18 (-1.2).

For both sprint distances the large negative effect sizes indicate that for each inter-level comparison the older cohorts were faster when compared to their younger counterparts, albeit not statistically significantly different.

On analysis of 10m Momentum large effect sizes were between the following comparisons: BAS2 v U16 (0.9); BAS3 v U16 (1.4); BAS2 v U18 (1.0) and BAS3 v U18 (1.4). These positive large effect sizes indicate that the older cohorts produced more momentum over 10m compared to the younger cohort for each age group comparison.

**Aerobic Fitness**

No statistically significant differences were present for aerobic fitness outcome measures. However, large effect sizes were evident for YoYo IRT-1 Predicted $\dot{V}O_2max$ suggesting the older cohorts were aerobically fitter for all of the following comparisons, albeit not significantly: U18 v U16 (0.9); BAS3 v U16 (1.2) and BAS3 v BAS2 (1.0).

**Anaerobic Fitness**

No analysis could be completed for BAS3 players due to insufficient numbers completing the test at this testing point. No statistical significant differences were evident for either of the outcome measures. A large effect sizes was seen for RSA MT U18 v U16 (-1.0).

The large negative effect sizes displayed above indicate that the U18 cohort were faster than the U16 cohort for the anaerobic fitness outcome measures.

**Agility**

No BAS3 data were available for Agility 505 analysis. A statistically significant difference occurred between U18 v U16 (-0.37, -0.04) for the 505 Left with a mean difference of 0.20s. A large effect size was present, BAS2 v U16 (-1.2).

For 505 Right, there were no significant differences for any of the comparisons made between age groups; however, a large effect size was present, U18 v U16 (-1.0).

The large negative effect sizes above highlight that per comparison the older cohort was faster than the younger cohort.

**Mental Toughness**

For the four outcome measures recorded from the SMTQ, there were no statistically significant differences present between any of the playing levels; however one large effect size was evident:

1. Control: BAS3 v BAS2 (-0.8)

This indicates that the younger BAS2 cohort had on average better Control scores compared to the older BAS3 cohort.

### 4.3.2 Forwards

*Table 9: Performance outcomes for the forwards only across the different stages of Academy development at the end of a competitive season, Testing Point 3.*

| Output Measures | U16 | | U18 | | Stage 2 | | Stage 3 | |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 10 | 94.2±14.2 | 4 | 93.7±14.6 | 5 | 98.5±9.7 | 5 | 109.4±4.5 |
| BF (%) | 10 | 23.0±11.2 | 4 | 20.2±4.2 | 5 | 19.3±8.3 | 5 | 14.8±4.1 |
| FFM (kg) | 10 | 71.4±6.4 | 4 | 74.4±8.4 | 5 | 78.8±2.5 | 5 | 93.1±3.5 |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 9 | 6.0±1.0 | 3 | 4.0±2.0 | 3 | 5.0±2.0 | - | - |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 9 | 30.3±4.6 | 3 | 35.8±4.1 | 4 | 39.3±3.8 | 2 | 47.9±12.6 |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 10 | 109.5±18.5 | 3 | 125.0±32.8 | - | - | 5 | 188.8±18.2 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 10 | 499.4±102.7 | 3 | 561.1±173.1 | - | - | 5 | 902.7±85.7 |
| 3RM Bench (kg) | 10 | 75.4±8.5 | 3 | 81.7±7.6 | 2 | 120.0±0.0 | 4 | 142.6±15.2 |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 10 | 3.7±0.4 | 3 | 4.1±0.3 | 2 | 5.6±0.2 | 4 | 6.3±0.6 |
| 3RM Chin (kg) | 7 | 104.3±10.2 | 3 | 107.4±14.8 | 2 | 115.3±5.0 | 3 | 145.3±6.8 |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 7 | 470.8±72.5 | 3 | 480.9±91.4 | 2 | 536.0±31.8 | 3 | 692.9±34.2 |
| **Speed** | | | | | | | | |
| 10m (s) | 9 | 1.88±0.12 | 3 | 1.78±0.12 | 4 | 1.83±0.12 | 2 | 1.74±0.05 |
| 30m (s) | 9 | 4.65±0.33 | 3 | 4.41±0.14 | 2 | 4.24±0.9 | - | - |
| 10m Momentum (kgm/s) | 9 | 497.1±59.8 | 3 | 499.0±73.3 | 3 | 576.8±52.0 | 2 | 637.9±21.2 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 5 | 42.8±2.2 | 2 | 49.3±5.0 | 4 | 47.5±2.0 | 2 | 49.0±3.1 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 9 | 5.10±0.51 | 3 | 4.68±0.34 | 3 | 4.88±0.29 | - | - |
| RSA % Decrement | 9 | 5.3±1.8 | 3 | 3.9±2.1 | 3 | 4.4±1.6 | - | - |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 8 | 2.55±0.13 | 3 | 2.39±0.10 | 3 | 2.44±0.04 | - | - |
| 505 Right Foot (s) | 8 | 2.52±0.13 | 3 | 2.40±0.11 | 3 | 2.46±0.10 | - | - |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 8 | 19.0±1.0 | 4 | 20.0±3.0 | 3 | 19.0±2.0 | 3 | 18.0±5.0 |
| Constancy (Out of 16) | 8 | 10.0±1.0 | 4 | 10.0±1.0 | 3 | 10.0±1.0 | 3 | 9.0±3.0 |
| Control (Out of 16) | 8 | 12.0±2.0 | 4 | 12.0±3.0 | 3 | 13.0±0.0 | 3 | 10.0±2.0 |
| Total (Out of 56) | 8 | 41.0±4.0 | 4 | 42.0±4.0 | 3 | 42.0±3.0 | 3 | 38.0±9.0 |

### 4.3.3 Backs

*Table 10: Performance outcomes for the backs only across the different stages of Academy development at the end of a competitive season, Testing Point 3.*

| **Output Measures** | | **U16** | | **U18** | | **Stage 2** | | **Stage 3** |
|---|---|---|---|---|---|---|---|---|
| | N | Mean±SD | N | Mean±SD | N | Mean±SD | N | Mean±SD |
| **Anthropometric** | | | | | | | | |
| Body Mass (kg) | 4 | 70.4±9.6 | 4 | 76.1±7.6 | 2 | 82.2±1.5 | 4 | 88.0±11.1 |
| BF (%) | 4 | 14.6±1.9 | 4 | 14.6±2.9 | 2 | 13.2±0.6 | 4 | 13.6±5.4 |
| FFM (kg) | 4 | 60.2±8.8 | 4 | 64.8±4.4 | 2 | 71.4±0.8 | 4 | 75.9±9.2 |
| **Functional Movement** | | | | | | | | |
| Tuck Jump Score (Out of 10) | 3 | 6.0±1.0 | 4 | 4.0±1.0 | 2 | 5.0±1.0 | 2 | 4.0±1.0 |
| **Lower Body Power** | | | | | | | | |
| CMJ (cm) | 3 | 37.9±3.7 | 3 | 36.7±4.0 | 2 | 43.1±2.3 | 2 | 54.2±6.4 |
| **Strength** | | | | | | | | |
| 3RM Squat (kg) | 3 | 113.3±25.7 | 4 | 121.3±13.2 | - | - | 3 | 156.7±14.6 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | 3 | 464.2±124.0 | 3 | 486.7±32.8 | - | - | 3 | 705.3±94.7 |
| 3RM Bench (kg) | 4 | 70.8±9.6 | 3 | 78.3±5.8 | - | - | 3 | 113.0±14.9 |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | 4 | 4.1±0.2 | 3 | 4.4±0.1 | - | - | 3 | 5.9±0.7 |
| 3RM Chin (kg) | 4 | 95.4±11.1 | 3 | 93.5±0.4 | - | - | - | - |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | 4 | 394.6±62.4 | 3 | 395.5±17.1 | - | - | - | - |
| **Speed** | | | | | | | | |
| 10m (s) | 3 | 1.76±0.04 | 3 | 1.74±0.08 | 2 | 1.74±0.04 | 2 | 1.69±0.13 |
| 30m (s) | 3 | 4.30±0.19 | 3 | 4.25±0.14 | 2 | 4.23±0.20 | 2 | 4.15±0.15 |
| 10m Momentum (kgm/s) | 3 | 383.7±57.8 | 3 | 436.8±60.9 | 2 | 474.2±18.2 | 2 | 509.5±33.3 |
| **Aerobic Fitness** | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | 3 | 50.3±1.6 | 2 | 49.8±5.7 | - | - | 2 | 50.7±3.1 |
| **Anaerobic Fitness** | | | | | | | | |
| RSA Mean Time (s) | 3 | 4.55±0.14 | 3 | 4.52±0.14 | - | - | - | - |
| RSA % Decrement | 3 | 3.0±1.7 | 3 | 6.3±1.0 | - | - | - | - |
| **Agility** | | | | | | | | |
| 505 Left Foot (s) | 3 | 246±0.05 | 2 | 2.22±0.13 | - | - | - | - |
| 505 Right Foot (s) | 3 | 2.36±0.10 | 2 | 2.27±0.06 | - | - | - | - |
| **Mental Toughness** | | | | | | | | |
| Confidence (Out of 24) | 4 | 19.0±1.0 | 4 | 19.0±2.0 | 2 | 21.0±5.0 | 3 | 19.0±2.0 |
| Constancy (Out of 16) | 4 | 11.0±1.0 | 4 | 11.0±2.0 | 2 | 10.0±2.0 | 3 | 11.0±1.0 |
| Control (Out of 16) | 4 | 12.0±2.0 | 4 | 12.0±1.0 | 2 | 11.0±3.0 | 3 | 12.0±1.0 |
| Total (Out of 56) | 4 | 42.0±3.0 | 4 | 41.0±3.0 | 2 | 41.0±10.0 | 3 | 42.0±2.0 |

## 4.4 Longitudinal Testing Comparisons

The tables and graphs below, pages 54–88, are split into clusters of specific performance measures. For each outcome measure, comparisons across the three testing points over the season, for each level of rugby are presented. At each level of rugby, comparisons across the season are shown for each age group as Whole Squads. Data shown were calculated from the latter Testing Point minus the earlier Testing Point e.g. Testing Point 1 → Testing Point 2 is calculated by taking data from Testing Point 2 minus Testing Point 1 (Testing Point 2 – Testing Point 1). Statistically significant differences are highlighted within the tables in bold and also written underneath. The graphs are representing a visual image of the descriptive statistics.

### 4.4.1 Whole Squad Longitudinal Anthropometric Measurements

*Table 11: U16 Whole Squad Longitudinal Anthropometric Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anthropometric** | | | | | | | | | |
| Body Mass (kg) | (-9.3, 15.9) | 3.3 | 5.2 | (-9.9, 16.3) | 3.2 | 5.4 | (-7.0, 19.9) | 6.5 | 5.5 |
| BF (%) | (-6.4, 8.7) | 1.2 | 3.1 | (-5.2, 10.4) | 2.6 | 3.2 | (-4.1, 11.7) | 3.8 | 3.3 |
| FFM (kg) | (-7.1, 7.8) | 0.4 | 3.1 | (-6.5, 9.0) | 1.3 | 3.2 | (-6.2, 9.5) | 1.6 | 3.2 |

For U16 Whole Squad longitudinal anthropometric measures, none of the time point comparisons highlight statistically significant differences. However, although not statistically proven, a greater change in BF (%) difference of means from Testing Point 1 → Testing Point 3 in comparison to FFM change. This indicates that the U16 players had a greater increase in BF (%) across the competitive season.

### 4.4.1 Whole Squad Longitudinal Anthropometric Measurements Continued

*Table 12: U18 Whole Squad Longitudinal Anthropometric Changes*

| Output Measures | Testing Point1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anthropometric** | | | | | | | | | |
| Body Mass (kg) | (-13.2, 15.3) | 1.0 | 5.8 | (-9.6, 20.9) | 5.6 | 6.2 | (-9.4, 22.7) | 6.6 | 6.5 |
| BF (%) | (-3.1, 6.4) | 1.7 | 1.9 | (-3.4, 6.7) | 1.7 | 2.0 | (-1.9, 8.6) | 3.3 | 2.1 |
| FFM (kg) | (-11.0, 9.8) | -0.6 | 4.2 | (-7.8, 14.3) | 3.2 | 4.5 | (-8.9, 14.1) | 2.6 | 4.6 |

Similarly to U16 anthropometric data, no statistically significant differences were evident for U18 data. It should be noted that there was a 'difference of means' of -0.6kg for FFM from Testing Point 1 → Testing Point 2 suggesting that the U18 cohort had less FFM at Testing Point 2. A 'difference of means' of 3.3% for BF (%) was also evident suggesting that the U18 cohort had a higher BF (%) at the end of the season compared to pre-season. This was not significant as the 95% CI indicates that they could be anywhere between 1.9% less to 8.6% more body fat. It could be suggested as the 95% CI approaches zero there is a trend towards them having a higher body fat percentage at the end of the season.

### 4.4.1 Whole Squad Longitudinal Anthropometric Measurements Continued

*Table 13: BAS2 Whole Squad Longitudinal Anthropometric Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anthropometric** | | | | | | | | | |
| Body Mass (kg) | (-9.9, 17.5) | 3.8 | 5.4 | (-17.3, 11.0) | -3.2 | 5.6 | (-13.5, 14.8) | 0.6 | 5.6 |
| BF (%) | (-9.6, 12.5) | 1.5 | 4.3 | (-10.1, 12.6) | 1.3 | 4.5 | (-7.9, 13.3) | 2.7 | 4.1 |
| FFM (kg) | (-5.7, 8.4) | 1.3 | 2.8 | (-10.6, 3.9) | -3.4 | 2.8 | (-8.8, 4.7) | -2.1 | 2.6 |

Analysis of Whole Squad BAS2 anthropometric longitudinal changes resulted in no statistically significant differences being found. However, it is evident from Table 13 that this group of players trended towards a large decrease in FFM in the second half of the competitive season. This resulted in a 'difference of means' of -2.1kg for FFM from Testing Point 1 → Testing Point 3. In conjunction with this, body mass 'difference of means' was 0.6kg, while, the BF (%) 'difference of means' increased by 2.7%.

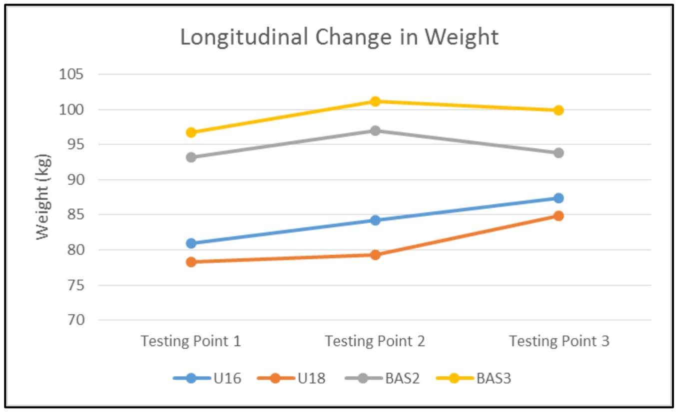
### 4.4.1 Whole Squad Longitudinal Anthropometric Measurements Continued

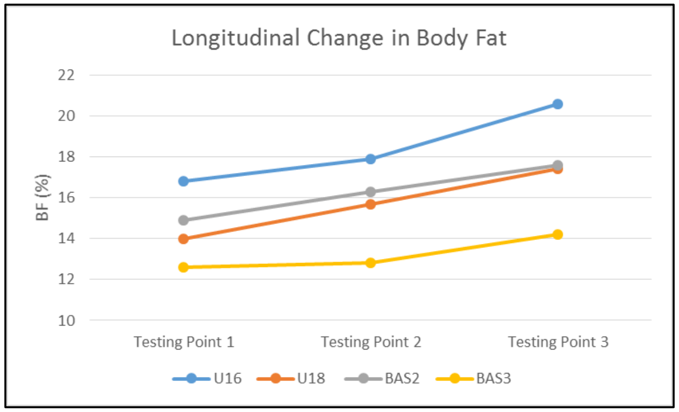
*Table 14: BAS3 Whole Squad Longitudinal Anthropometric Changes*

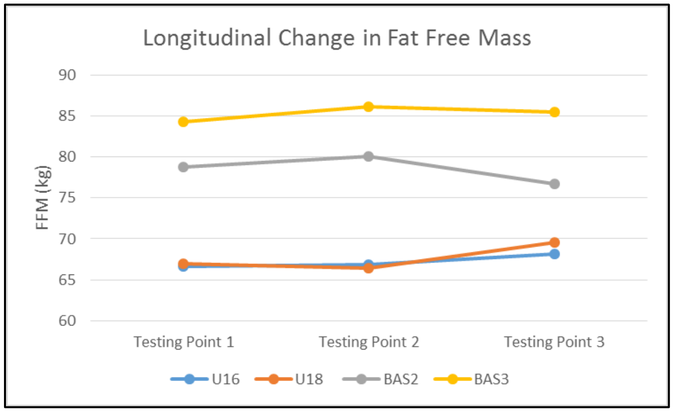
| **Output Measures** | **Testing Point 1 → Testing Point 2** | | | **Testing Point 2 → Testing Point 3** | | | **Testing Point 1 → Testing Point 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anthropometric** | | | | | | | | | |
| Body Mass (kg) | (-13.8, 15.7) | 1.0 | 6.0 | (-13.4, 17.7) | 2.2 | 6.3 | (-12.1, 18.3) | 3.1 | 6.1 |
| BF (%) | (-4.8, 5.3) | 0.3 | 2.0 | (-3.9, 6.7) | 1.4 | 2.1 | (-3.0, 6.4) | 1.7 | 1.9 |
| FFM (kg) | (-11.0, 14.6) | 1.8 | 5.1 | (-14.0, 12.7) | -0.7 | 5.4 | (-10.8, 13.0) | 1.1 | 4.8 |

No statistically significant differences were evident for the BAS3 athletes for any of the anthropometric outcome measures. This was the consistent with all other age groups results.

## 4.4.1 Whole Squad Longitudinal Anthropometric Measurements Continued




*Figures 2a-c: Line graphs highlighting the longitudinal change for anthropometric variables across all age groups*

### 4.4.2 Whole Squad Longitudinal Functional Movement Measurement

*Table 15: U16 Whole Squad Longitudinal Functional Movement Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Functional Movement** | | | | | | | | | |
| Tuck Jump Score | **(-3.0, 0.0)** | **-2.0** | **0.0** | **(0.0, 3.0)** | **2.0** | **1.0** | (-1.0, 1.0) | 0.0 | 0.0 |

Statistically significant differences existed for the U16 cohort in Tuck Jump scores from Testing Point 1 → Testing Point 2 where scores improved as indicated by the negative difference of means. However, from Testing Point 2 → Testing Point 3, scores reduced as a positive difference of means for Tuck Jump indicates a higher score – therefore poorer performance. Although changes occurred during the season there was no overall improvement from the start to end of season as indicated by a ‘difference of means’ of 0.0AU.

*Table 16: U18 Whole Squad Longitudinal Functional Movement Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Functional Movement** | | | | | | | | | |
| Tuck Jump Score | (-2.0, 1.0) | 0.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 | (-2.0, 1.0) | 0.0 | 1.0 |

U18 Whole Squad longitudinal Tuck Jump scores show no statistically significant differences across the season.

### 4.4.2 Whole Squad Longitudinal Functional Movement Measurements Continued

*Table 17: BAS2 Whole Squad Longitudinal Functional Movement Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Functional Movement** | | | | | | | | | |
| Tuck Jump Score | (-2.0, 2.0) | 0.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 |

Tuck Jump scores for the BAS2 cohort remained at the same level across the season resulting in no improvement or statistically significant differences.

*Table 18: BAS3 Whole Squad Longitudinal Functional Movement Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Functional Movement** | | | | | | | | | |
| Tuck Jump Score | (-2.0, 1.0) | -1.0 | 0.0 | (-3.0, 1.0) | -1.0 | 1.0 | (-3.0, 1.0) | -1.0 | 1.0 |

No statistically significant differences were calculated for BAS3 Tuck Jump data across the season.

### 4.4.2 Whole Squad Longitudinal Functional Movement Measurements Continued

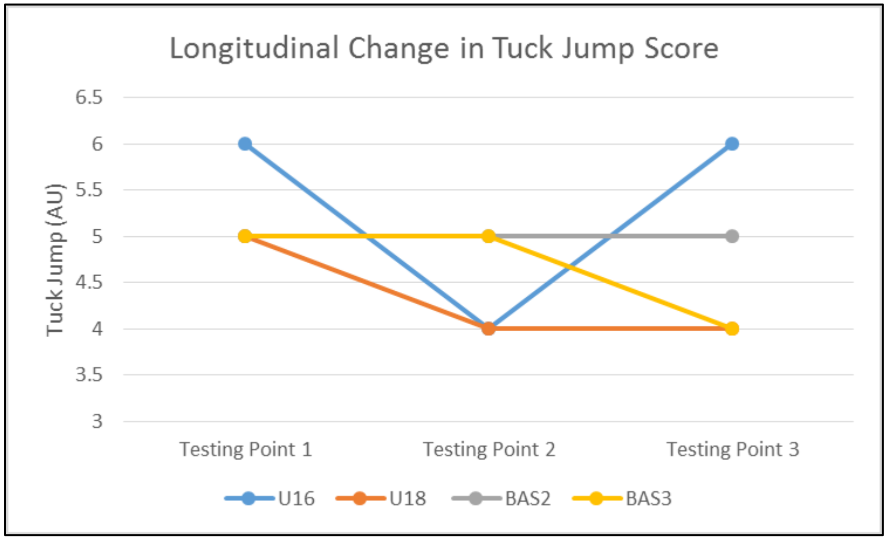



*Figure 3: The longitudinal change in tuck jump scores for all Whole Squad cohorts*

### 4.4.3 Whole Squad Longitudinal Lower Body Power Measurements

*Table 19: U16 Whole Squad Longitudinal Lower Body Power Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Lower Body Power** | | | | | | | | | |
| CMJ (cm) | (-1.2, 6.8) | 2.8 | 1.6 | (-4.3, 4.4) | 0.0 | 1.8 | (-1.4, 7.1) | 2.8 | 1.7 |

No statistically significant difference was evident in CMJ data for the U16 cohort. Although not significant, a small change in testing scores occurred across the season with the 'difference of means' increasing by 2.8cm. It might be suggested as the 95% CI is approaching zero, there is a trend towards being significant.

### 4.4.3 Whole Squad Longitudinal Lower Body Power Measurements Continued

*Table 20: U18 Whole Squad Longitudinal Lower Body Power Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Lower Body Power** | | | | | | | | | |
| CMJ (cm) | (-1.0, 9.2) | 4.1 | 2.1 | (-9.7, 2.5) | -3.6 | 2.5 | (-5.6, 6.6) | 0.5 | 2.5 |

No statistically significant differences were seen for U18 CMJ testing data. There was a ‘difference of means’ of 4.1cm from Testing Point 1 → Testing Point 2, suggesting the U18 cohort jumped higher at Testing Point 2 compared to Testing Point 1. This was not significant as the 95% CI indicates that they could be anywhere between 1cm lower up to 9.2cm higher. It might be suggested that as the 95% CI is approaching zero, there is a trend towards them jumping higher at mid-season. From the data it can be seen that the opposite occurred from Testing Point 2 → Testing Point 3 with a ‘difference of means’ of -3.6cm suggesting they jumped lower at the end of the season compared to mid-season.

### 4.4.3 Whole Squad Longitudinal Lower Body Power Measurements Continued

*Table 21: BAS2 Whole Squad Longitudinal Lower Body Power Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Lower Body Power** | | | | | | | | | |
| CMJ (cm) | (-7.2, 8.7) | 0.7 | 3.1 | (-9.7, 6.2) | -1.7 | 3.1 | (-9.5, 7.5) | -1.0 | 3.3 |

No statistically significant differences were evident for BAS2 CMJ testing data across the season.

*Table 22: BAS3 Whole Squad Longitudinal Lower Body Power Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Lower Body Power** | | | | | | | | | |
| CMJ (cm) | (-8.6, 11.3) | 1.3 | 3.9 | (-5.2, 19.2) | 7.0 | 4.8 | (-3.9, 20.6) | 8.4 | 4.8 |

No statistically significant differences were present.  However, it should be noted that the BAS3 cohort was trending towards an improvement from Testing Point 1 → Testing Point 3 as the 95% CI is approaching zero.

### 4.4.3 Whole Squad Longitudinal Lower Body Power Measurements Continued

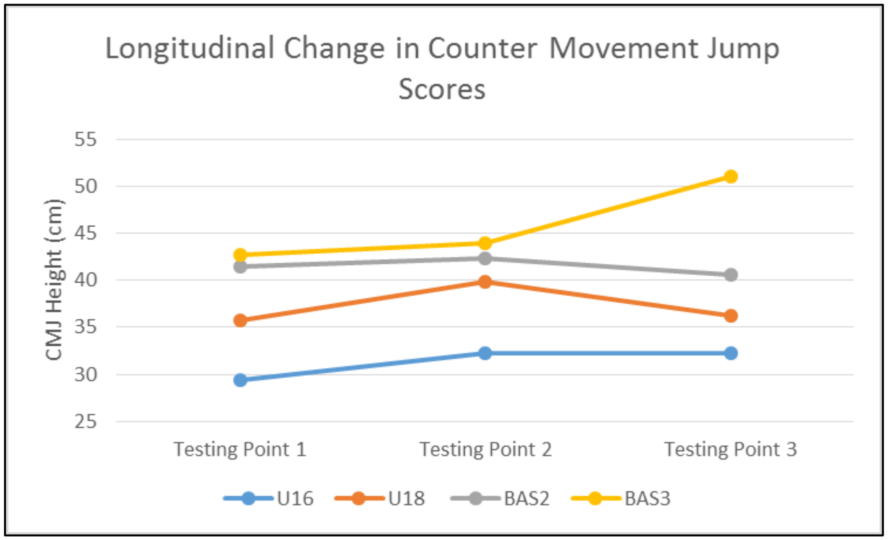



*Figure 4: Line graphs highlighting the longitudinal change for all playing levels for lower body power measurement - CMJ*

### 4.4.4 Whole Squad Longitudinal 3RM Strength Measurements

*Table 23: U16 Whole Squad Longitudinal 3RM Strength Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Strength** | | | | | | | | | |
| 3RM Squat (kg) | (-6.1, 27.0) | 10.4 | 6.8 | (-14.8, 20.6) | 2.9 | 7.3 | (-2.0, 28.6) | 13.3 | 6.3 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | (-188.0, 71.1) | -58.4 | 53.1 | (-4.1, 268.1) | 132.0 | 55.8 | (-56.0, 203.1) | 73.5 | 53.1 |
| 3RM Bench (kg) | (-2.2, 12.9) | 5.4 | 3.1 | (-4.0, 12.0) | 4.0 | 3.3 | **(2.0, 16.7)** | **9.4** | **3.0** |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | (-1.0, 0.5) | -0.2 | 0.3 | (-0.3, 1.3) | 0.6 | 0.3 | (-0.5, 1.1) | 0.3 | 0.3 |
| 3RM Chin (kg) | (-6.4, 13.8) | 3.7 | 4.1 | (-5.7, 16.6) | 5.5 | 4.6 | (-1.8, 20.2) | 9.2 | 4.5 |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | (-98.7, 86.4) | 23.9 | 25.6 | (-47.8, 90.4) | 21.3 | 28.3 | (-22.9, 113.4) | 45.2 | 27.9 |

Bench 3RM significantly improved from Testing Point 1 → Testing Point 3 with players lifting anywhere between 2.0kg to 16.7kg more by the end of the season. Although not significant, a positive 'difference of means' for all other outcome measures suggests the U16 were stronger when data were analysed across the season. 3RM Squat trending towards an improvement as the 95% CI is approaching zero.

### 4.4.4 Whole Squad Longitudinal 3RM Strength Measurements Continued

*Table 24: U18 Whole Squad Longitudinal 3RM Strength Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Strength** | | | | | | | | | |
| 3RM Squat (kg) | (-11.2, 35.5) | 12.1 | 9.4 | (-27.3, 21.0) | -3.1 | 9.7 | (-16.2, 34.3) | 9.0 | 10.1 |
| Squat Allometric Scaling (Perf/$BW^{-1/3}$) | (-154.5, 178.6) | 12.0 | 66.7 | (-154.0, 223.8) | 34.9 | 75.7 | (-152.1, 246.0) | 46.9 | 79.8 |
| 3RM Bench (kg) | (-5.5,19.7) | 7.1 | 5.1 | (-18.0, 9.6) | -4.2 | 5.6 | (-11.1, 16.9) | 2.9 | 5.7 |
| Bench Allometric Scaling (Perf/$BW^{2/3}$) | (-1.5, 0.9) | -0.3 | 0.5 | (-0.9, 2.0) | 0.5 | 0.6 | (-1.3, 1.7) | 0.2 | 0.6 |
| 3RM Chin (kg) | (-13.1, 17.1) | 2.0 | 6.0 | (13.3, 21.6) | 4.2 | 7.0 | (-11.3, 23.6) | 6.2 | 7.0 |
| Chin Allometric Scaling (Perf/$BW^{-1/3}$) | (-236.0, 64.4) | -85.8 | 60.5 | (-56.5, 295.9) | 119.7 | 71.0 | (-150.5, 218.3) | 33.9 | 74.3 |

No statistically significant differences were evident across the season.

*Table 25: BAS2 Whole Squad Longitudinal 3RM Strength Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Strength** | | | | | | | | | |
| 3RM Squat (kg) | (-31.8, 49.2) | 8.7 | 17.9 | - | - | - | - | - | - |
| Squat Allometric Scaling (Perf/$BW^{-1/3}$) | (-612.0, 124.0) | -244.0 | 169.0 | - | - | - | - | - | - |
| 3RM Bench (kg) | (-7.1, 19.0) | 6.0 | 4.9 | - | - | - | - | - | - |
| Bench Allometric Scaling (Perf/$BW^{2/3}$) | (-0.5, 0.8) | 0.1 | 0.3 | - | - | - | - | - | - |
| 3RM Chin (kg) | (-50.5, 8.6) | -21.0 | 11.4 | - | - | - | - | - | - |
| Chin Allometric Scaling (Perf/$BW^{-1/3}$) | (-136.5, 35.8) | -50.4 | 32.9 | - | - | - | - | - | - |

No statistically significant differences were evident, for BAS2 from Testing Point 1 → Testing Point 2.

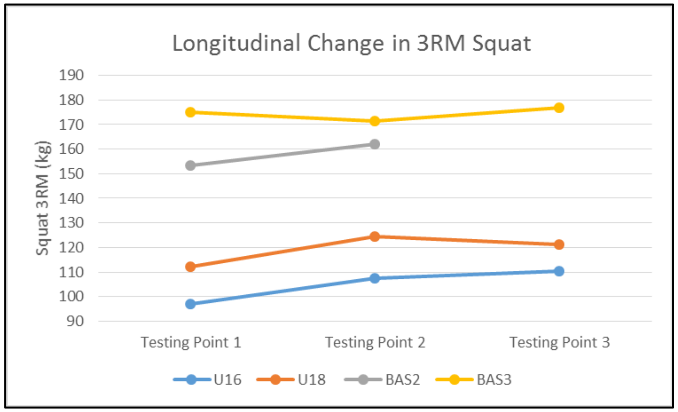
### 4.4.4 Whole Squad Longitudinal 3RM Strength Measurements Continued

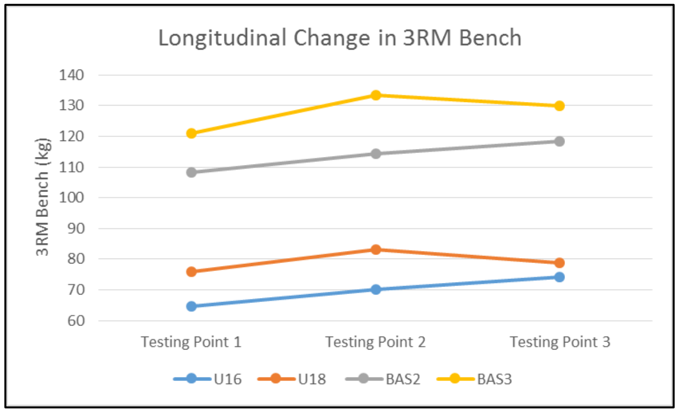
*Table 26: BAS3 Whole Squad Longitudinal 3RM Strength Changes*

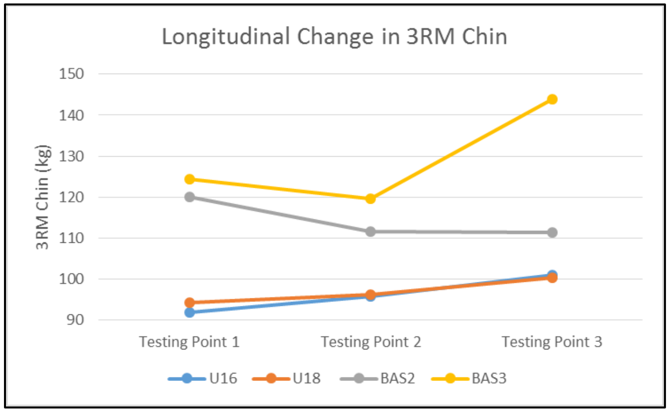
| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Strength** | | | | | | | | | |
| 3RM Squat (kg) | (-42.5, 22.5) | -10.0 | 12.8 | (-19.7, 43.2) | 11.7 | 12.4 | (-29.7, 33.2) | 1.7 | 12.4 |
| Squat Allometric Scaling (Perf/BW$^{-1/3}$) | (-232.6, 126.9) | -52.8 | 70.8 | (-99.1, 248.9) | 74.9 | 68.6 | (-152.0, 196.1) | 22.1 | 68.6 |
| 3RM Bench (kg) | (-35.3, 22.1) | -6.6 | 11.2 | (-10.5, 41.6) | 15.6 | 10.1 | (-20.5, 38.4) | 8.9 | 11.5 |
| Bench Allometric Scaling (Perf/BW$^{2/3}$) | (-1.4, 0.9) | -0.2 | 0.4 | (-0.5, 1.5) | 0.5 | 0.4 | (-0.9, 1.4) | 0.2 | 0.4 |
| 3RM Chin (kg) | - | - | - | (-22.3, 13.0) | -4.7 | 6.6 | - | - | - |
| Chin Allometric Scaling (Perf/BW$^{-1/3}$) | - | - | - | (-149.3, 65.0) | 42.2 | 40.2 | - | - | - |

No statistically significant differences were evident for the BAS3 cohort’s longitudinal data.

### 4.4.4 Whole Squad Longitudinal 3RM Strength Measurements Continued

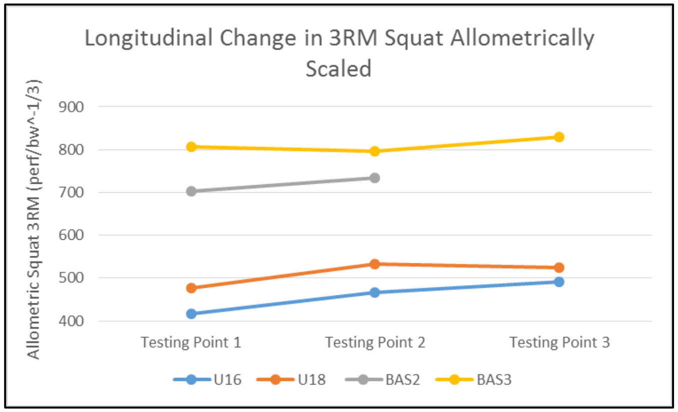


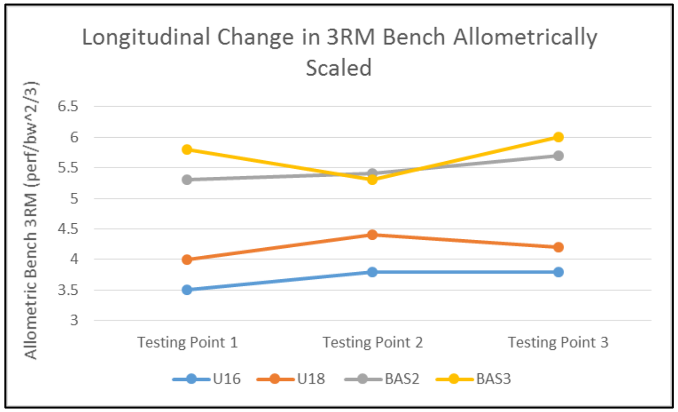



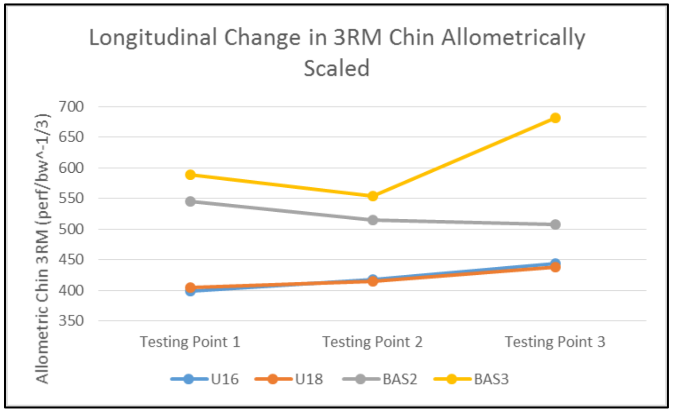




*Figures 5a-c:* Line graphs showing the longitudinal change of 3RM absolute strength data for each playing level

## 4.4.4 Whole Squad Longitudinal 3RM Strength Measurements Continued




*Figures 6a-c: Line graphs showing the longitudinal change of 3RM absolute strength data scaled allometrically for each playing level*

### 4.4.5 Whole Squad Longitudinal Speed Measurements

*Table 27: U16 Whole Squad Longitudinal Speed Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Speed** | | | | | | | | | |
| 10m (s) | (-0.07, 0.14) | 0.03 | 0.04 | (-0.09, 0.13) | 0.02 | 0.05 | (-0.05, 0.16) | 0.05 | 0.04 |
| 30m (s) | (-0.25, 0.30) | 0.03 | 0.11 | (-0.23, 0.37) | 0.07 | 0.12 | (-0.18, 0.38) | 0.10 | 0.12 |
| 10m Momentum (kgm/s) | (-56.6, 74.7) | 9.0 | 26.9 | (-67.0, 72.0) | 2.5 | 28.5 | (-56.9, 79.9) | 11.5 | 28.0 |

No statistically significant differences were calculated for U16 speed data. Although not statistically different, a positive ‘difference of means’ for 10m and 30m sprint times suggests the U16 cohort became slower across the season, whereas 10m Momentum produced a ‘difference of means’ of 11.5kgm/s suggesting more Momentum was produced over 10m across the season. It is reasonable to assume this can be attributed to the increase in body mass.

### 4.4.5 Whole Squad Longitudinal Speed Measurements Continued

*Table 28: U18 Whole Squad Longitudinal Speed Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Speed** | | | | | | | | | |
| 10m (s) | (-0.05, 0.09) | 0.02 | 0.03 | (-0.08, 0.10) | 0.01 | 0.04 | (-0.06, 0.12) | 0.03 | 0.04 |
| 30m (s) | (-0.22, 0.15) | -0.03 | 0.08 | (-0.11, 0.34) | 0.12 | 0.09 | (-0.14, 0.31) | 0.08 | 0.09 |
| 10m Momentum (kgm/s) | (-53.7, 107.3) | 26.8 | 32.1 | (-86.1, 95.6) | 4.7 | 36.3 | (-62.8, 125.9) | 31.5 | 37.7 |

No statistically significant differences were calculated for U18 Speed data across the season.

*Table 29: BAS2 Whole Squad Longitudinal Speed Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Speed** | | | | | | | | | |
| 10m (s) | (-0.14, 0.15) | 0.01 | 0.06 | (-0.08, 0.15) | 0.03 | 0.04 | (-0.11, 0.19) | 0.04 | 0.06 |
| 30m (s) | (-0.38, 0.23) | -0.07 | 0.11 | (-0.30, 0.25) | -0.03 | 0.10 | (-0.43, 0.24) | -0.10 | 0.13 |
| 10m Momentum (kgm/s) | (-125.4, 120.8) | -2.3 | 46.2 | (-113.2, 95.7) | -8.8 | 39.2 | (-141.4, 119.2) | -11.1 | 48.9 |

No statistically significant differences were evident across the season. Although, the BAS2 trended to be faster over 30m, they trended to be slower for 10m sprint times across the season. This resulted in less 10m Momentum from Testing Point 1 → Testing Point 3, indicated by a negative ‘difference of means’.

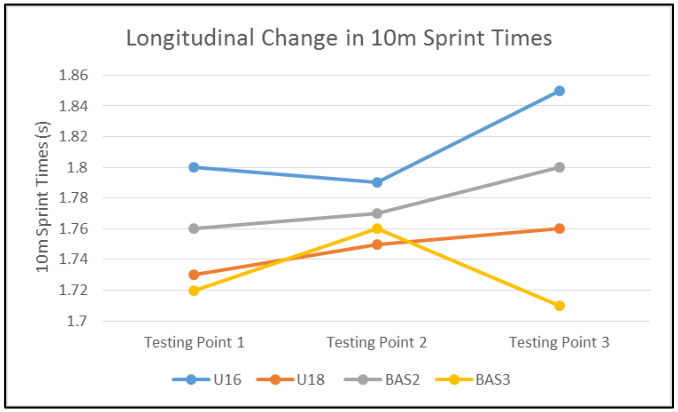
### 4.4.5 Whole Squad Longitudinal Speed Measurements Continued

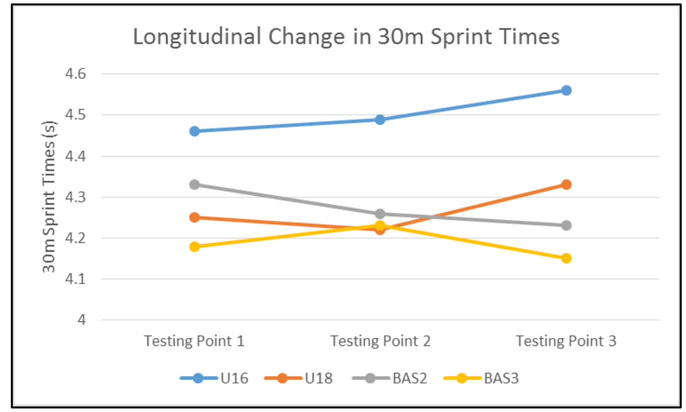
*Table 30: BAS3 Whole Squad Longitudinal Speed Changes*

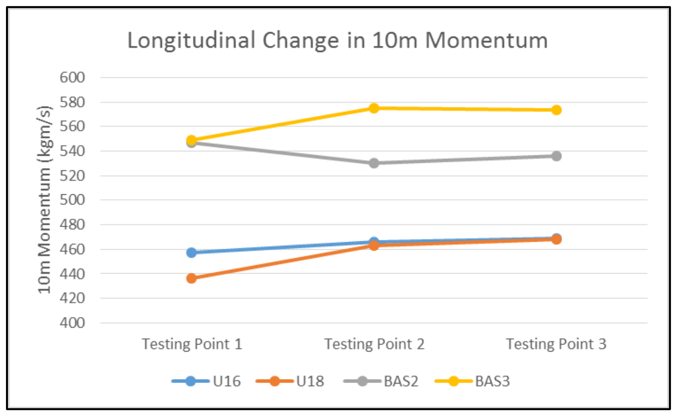
| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Speed** | | | | | | | | | |
| 10m (s) | (-0.11, 0.12) | 0.00 | 0.05 | (-0.17, 0.14) | -0.02 | 0.06 | (-0.17, 0.14) | -0.01 | 0.06 |
| 30m (s) | (-0.24, 0.23) | -0.01 | 0.09 | (-0.43, 0.37) | -0.03 | 0.16 | (-0.44, 0.37) | -0.04 | 0.16 |
| 10m Momentum (kgm/s) | (-64.3, 95.4) | 15.5 | 31.5 | (-93.5, 112.1) | 9.3 | 40.6 | (-79.6, 129.2) | 24.8 | 41.3 |

No statistically significant differences were evident across the season for BAS3. The negative 'difference of means' for both 10m and 30m sprint times suggests the BAS3 cohort were faster from Testing Point 1 → Testing Point 3.

### 4.4.5 Whole Squad Longitudinal Speed Measurements Continued




*Figures 7a-c: Line graphs highlighting the longitudinal changes for all speed outcome measures for all playing levels*

### 4.4.6 Whole Squad Longitudinal Aerobic Fitness Measurements

*Table 31: U16 Whole Squad Longitudinal Aerobic Fitness Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Aerobic Fitness** | | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | (-2.3, 4.7) | 1.2 | 1.4 | (-5.6, 3.2) | -1.2 | 1.8 | (-4.4, 4.3) | 0.0 | 1.8 |

No statistically significant differences were evident and no change in predicted $\dot{V}O_2max$ was seen from Testing Point 1 → Testing Point 3. The 'difference of means' of -1.2ml/kg/min suggests that the U16 cohort had lower fitness at Testing Point 3 compared to Testing Point 2. This was not significant as the 95% CI shows they could be between 5.6ml/kg/min less aerobically fit up to 3.2ml/kg/min more aerobically fit.

*Table 32: U18 Whole Squad Longitudinal Aerobic Fitness Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Aerobic Fitness** | | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | (-4.7, 5.0) | 0.2 | 2.0 | (-5.4, 5.9) | 0.3 | 2.3 | (-5.4, 6.3) | 0.4 | 2.4 |

No statistically significant differences were evident for U18 longitudinal Aerobic Fitness data.

### 4.4.6 Whole Squad Longitudinal Aerobic Fitness Measurements Continued

*Table 33: BAS2 Whole Squad Longitudinal Aerobic Fitness Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Aerobic Fitness** | | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | (-4.5, 5.1) | 0.3 | 1.8 | (-8.3, 2.5) | -2.9 | 2.1 | (-8.2, 3.0) | -2.6 | 2.1 |

No statistically significant differences were evident for BAS2 data across the season.

*Table 34: BAS3 Whole Squad Longitudinal Aerobic Fitness Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Aerobic Fitness** | | | | | | | | | |
| YoYo IRT-1 Predicted $\dot{V}O_2max$ (ml/kg/min) | (-5.9, 1.8) | -2.1 | 1.5 | (-4.2, 5.4) | 0.6 | 1.9 | (-5.7, 2.7) | -1.5 | 1.6 |

No statistically significant differences were evident for BAS3 longitudinal Aerobic Fitness testing data. There was a difference of means of -2.1ml/kg/min from Testing Point 1 → Testing Point 2 suggesting the BAS3 cohort were less aerobically fit at mid-season compared to pre-season. As the 95% CI is approaching zero, there is a trend towards being significant.

### 4.4.6 Whole Squad Longitudinal Aerobic Fitness Measurements Continued

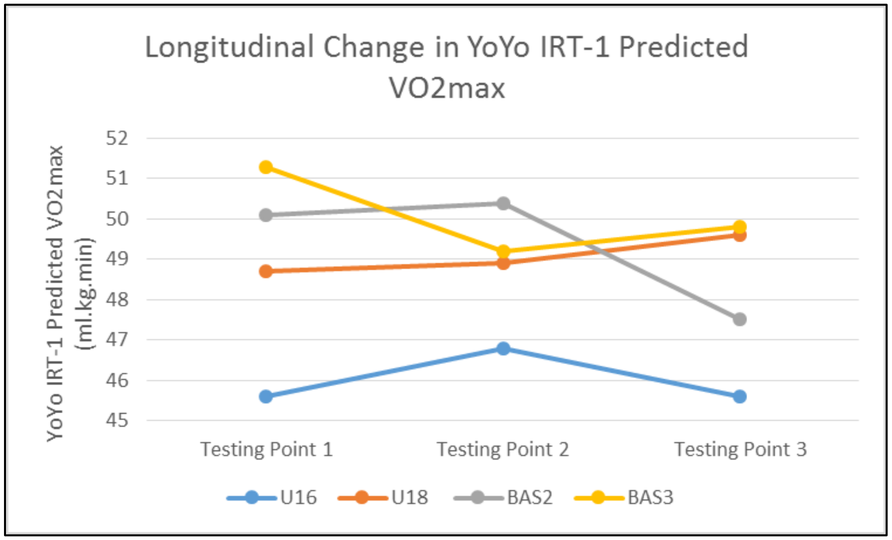



*Figure 8: Line graphs highlighting the longitudinal change in aerobic fitness*

### 4.4.7 Whole Squad Longitudinal Anaerobic Measurements

*Table 35: U16 Whole Squad Longitudinal Anaerobic Fitness Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anaerobic Fitness** | | | | | | | | | |
| RSA Mean Time (s) | (-0.33, 0.44) | 0.05 | 0.16 | (-0.41, 0.43) | 0.01 | 0.17 | (-0.34, 0.46) | 0.06 | 0.17 |
| RSA % Decrement | (-0.9, 2.5) | 0.8 | 0.7 | (-2.7, 0.9) | -0.9 | 0.7 | (-1.8, 1.7) | -0.1 | 0.7 |

No statistically significant differences were evident for U16 longitudinal Anaerobic Fitness data.

*Table 36: U18 Whole Squad Longitudinal Anaerobic Fitness Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anaerobic Fitness** | | | | | | | | | |
| RSA Mean Time (s) | (-0.21, 0.28) | 0.04 | 0.10 | (-0.37, 0.26) | -0.08 | 0.12 | (-0.33, 0.26) | -0.04 | 0.12 |
| RSA % Decrement | (-0.8, 3.1) | 1.1 | 0.8 | (-0.34, 1.3) | -1.0 | 1.0 | (-2.3, 2.5) | 0.1 | 1.0 |

No statistically significant differences were evident for U18 longitudinal Anaerobic Fitness data.

### 4.4.7 Whole Squad Longitudinal Anaerobic Measurements Continued

*Table 37: BAS2 Whole Squad Longitudinal Anaerobic Fitness Changes*

| **Output Measures** | **Testing Point 1 → Testing Point 2** | | | **Testing Point 2 → Testing Point 3** | | | **Testing Point 1 → Testing Point 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anaerobic Fitness** | | | | | | | | | |
| RSA Mean Time (s) | (-0.41, 0.46) | 0.03 | 0.16 | (-0.42, 0.54) | 0.06 | 0.18 | (-0.35, 0.52) | 0.09 | 0.16 |
| RSA % Decrement | (-1.4, 3.2) | 0.9 | 0.9 | **(-5.1, -0.1)** | **-2.6** | **0.9** | (-4.0, 0.6) | -1.7 | 0.9 |

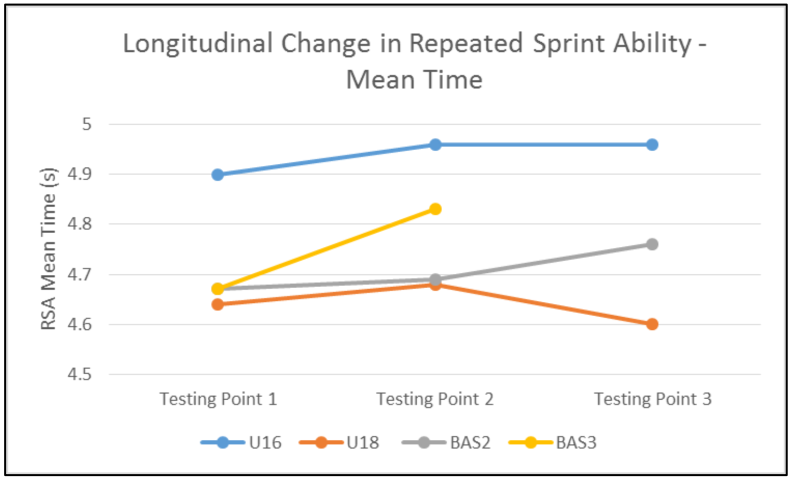
A statistically significant difference was seen for RSA % Decrement from Testing Point 2 → Testing Point 3. As a result a 'difference of means' of -1.7% for RSA % Decrement was seen over the competitive season; however, RSA Mean Time was slower indicated by a 'difference of means' of 0.09s. Although neither of these were significant it suggests that the BAS2 cohort were anaerobically fitter at the end of the season but had a slower RSA Mean Time. This is potentially due to each individual sprint times being slower but more consistent.

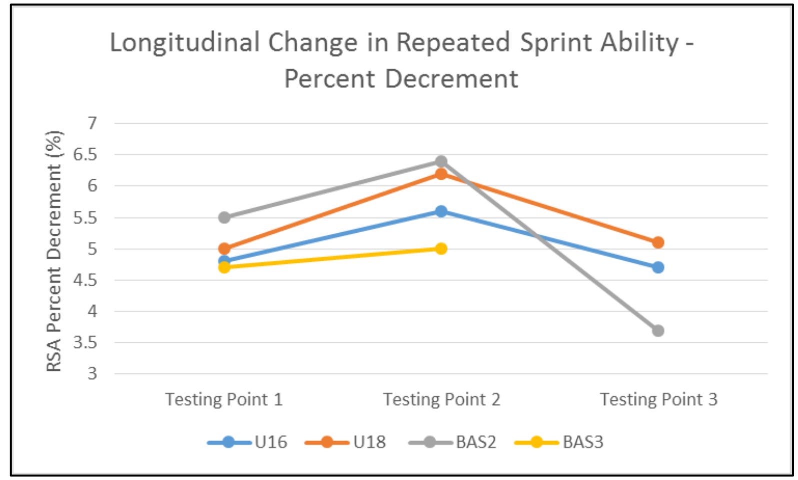
*Table 38: BAS3 Whole Squad Longitudinal Anaerobic Fitness Changes*

| **Output Measures** | **Testing Point 1 → Testing Point 2** | | | **Testing Point 2 → Testing Point 3** | | | **Testing Point 1 → Testing Point 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Anaerobic Fitness** | | | | | | | | | |
| RSA Mean Time (s) | (-0.03, 0.33) | 0.15 | 0.08 | - | - | - | - | - | - |
| RSA % Decrement | (-1.8, 2.5) | 0.3 | 0.9 | - | - | - | - | - | - |

No statistically significant differences were evident for BAS3 longitudinal Anaerobic Fitness data.

### 4.4.7 Whole Squad Longitudinal Anaerobic Measurements Continued




*Figures 9a-b: Line graphs highlighting the longitudinal changes in anaerobic fitness outcome measures across all age groups*

### 4.4.8 Whole Squad Longitudinal Agility Measurements

*Table 39: U16 Whole Squad Longitudinal Agility Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Agility** | | | | | | | | | |
| 505 Left Foot (s) | (-0.07, 0.21) | 0.07 | 0.06 | (-0.21, 0.00) | -0.14 | 0.06 | (-0.21, 0.06) | -0.07 | 0.06 |
| 505 Right Foot (s) | (-0.12, 0.17) | 0.02 | 0.06 | **(-0.31, -0.00)** | **-0.15** | **0.06** | (-0.28, 0.01) | -0.13 | 0.06 |

A statistically significant difference was calculated for the U16 cohort between Testing Point 2 and Testing Point 3 for 505 right foot. It should be noted that 505 Left Foot turn times between Testing Point 2 and Testing Point 3 is trending towards significance as the 95% CI is approaching zero.

*Table 40: U18 Whole Squad Longitudinal Agility Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Agility** | | | | | | | | | |
| 505 Left Foot (s) | (-0.14, 0.22) | 0.04 | 0.07 | (-0.37, 0.04) | -0.16 | 0.08 | (-0.31, 0.06) | -0.12 | 0.07 |
| 505 Right Foot (s) | (-0.19, 0.27) | 0.04 | 0.09 | (-0.42, 0.11) | -0.15 | 0.10 | (-0.36, 0.13) | -0.12 | 0.10 |

No statistically significant differences were calculated for the U18 cohort across the season.

### 4.4.8 Whole Squad Longitudinal Agility Measurements Continued

*Table 41: BAS2 Whole Squad Longitudinal Agility Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Agility** | | | | | | | | | |
| 505 Left Foot (s) | (-0.18, 0.19) | 0.00 | 0.07 | (-0.24, 0.11) | -0.07 | 0.06 | (-0.25, 0.13) | -0.06 | 0.07 |
| 505 Right Foot (s) | (-0.20, 0.23) | 0.01 | 0.08 | (-0.28, 0.13) | -0.08 | 0.07 | (-0.28, 0.16) | -0.06 | 0.08 |

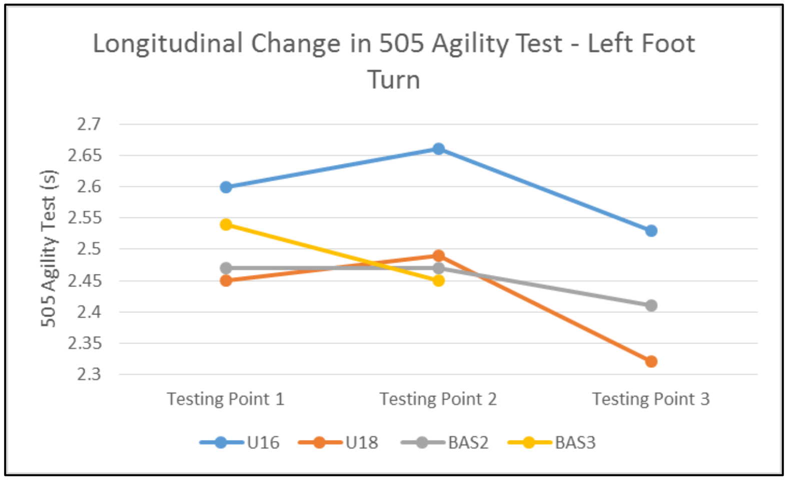
No statistically significant differences were evident for BAS2 Agility data across the season.

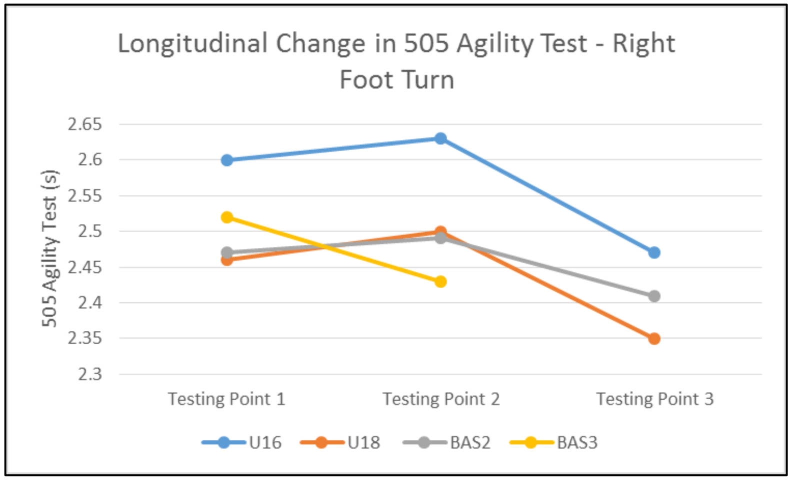
*Table 42: BAS3 Whole Squad Longitudinal Agility Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Agility** | | | | | | | | | |
| 505 Left Foot (s) | (-0.30, 0.12) | -0.09 | 0.10 | - | - | - | - | - | - |
| 505 Right Foot (s) | (-0.21, 0.05) | 0.08 | 0.06 | - | - | - | - | - | - |

No statistically significant differences were seen between Testing Point 1 and Testing Point 2. There was a 'difference of means' of 0.08s from Testing Point 1 → Testing Point 2. This suggests that the BAS3 cohort were faster at the start of the season compared to mid-season. This was not significant because the 95% CI shows they could be anywhere between 0.21s faster to 0.05s slower. It might be suggested as the 95% CI is approaching zero, there is a trend towards them being slower at Testing Point 2.

### 4.4.8 Whole Squad Longitudinal Agility Measurements Continued




*Figures 10a-b: Longitudinal changes in 505 Agility turn times of both feet illustrated in line graphs*

### 4.4.9 Whole Squad Longitudinal Psychological Measurements

*Table 43: U16 Whole Squad Longitudinal Psychological Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Mental Toughness** | | | | | | | | | |
| Confidence (Out of 24) | (-3.0, 1.0) | -1.0 | 1.0 | (-1.0, 3.0) | 1.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 |
| Constancy (Out of 16) | **(-5.0, -2.0)** | **-4.0** | **1.0** | (-1.0, 2.0) | 0.0 | 1.0 | **(-5.0, -2.0)** | **-3.0** | **1.0** |
| Control (Out of 16) | (-1.0, 2.0) | 1.0 | 1.0 | (-2.0, 1.0) | -1.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 |
| Total (Out of 56) | **(-8.0, 0.0)** | **-4.0** | **2.0** | (-3.0, 5.0) | 1.0 | 2.0 | (-7.0, 1.0) | -3.0 | 2.0 |

Statistically significant differences were seen for Constancy and Total from Testing Point 1 → Testing Point 2 and for Constancy – Testing Point 1 → Testing Point 3. All significant differences were negative which indicated a decrease in scores. There was a 'difference of means' of -3.0UA for Total suggesting the U16 cohort had lower Total Mental Toughness scores at the end of the season compared to pre-season. This was not significant because the 95% CI indicated that they could have scored anywhere between 7UA less to 1UA more. It might be suggested as the 95% CI is approaching zero, there is a trend towards them having lower Total Mental Toughness scores at the end of the season.

### 4.4.9 Whole Squad Longitudinal Psychological Measurements Continued

*Table 44: U18 Whole Squad Longitudinal Psychological Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Mental Toughness** | | | | | | | | | |
| Confidence (Out of 24) | (-1.0, 3.0) | 1.0 | 1.0 | (-1.0, 3.0) | 1.0 | 1.0 | (-1.0, 4.0) | 1.0 | 1.0 |
| Constancy (Out of 16) | **(-6.0, -3.0)** | **-4.0** | **1.0** | (-1.0, 2.0) | 0.0 | 1.0 | **(-6.0, -2.0)** | **-4.0** | **1.0** |
| Control (Out of 16) | (-1.0, 3.0) | 1.0 | 1.0 | (-2.0, 1.0) | -1.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 |
| Total (Out of 56) | (-6.0, 1.0) | -3.0 | 2.0 | (-4.0, 4.0) | 0.0 | 2.0 | (-7.0, 2.0) | -3.0 | 2.0 |

Statistically significant differences were seen for Constancy when comparing Testing Point 1 → Testing Point 2 and Testing Point 1 → Testing Point 3, albeit both were negative indicating a decrease in scores. Only Confidence had a positive 'difference of means' over the season, suggesting the U18 cohort had greater Confidence at the end of season – albeit not significant.

### 4.4.9 Whole Squad Longitudinal Psychological Measurements Continued

*Table 45: BAS2 Whole Squad Longitudinal Psychological Changes*

| Output Measures | Testing Point 1 → Testing Point 2 | | | Testing Point 2 → Testing Point 3 | | | Testing Point 1 → Testing Point 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Mental Toughness** | | | | | | | | | |
| Confidence (Out of 24) | (-6.0, 3.0) | -2.0 | 2.0 | (-4.0, 6.0) | 1.0 | 2.0 | (-5.0, 4.0) | -1.0 | 2.0 |
| Constancy (Out of 16) | **(-5.0, -2.0)** | **-4.0** | **1.0** | (-3.0, 1.0) | -1.0 | 1.0 | **(-7.0, -2.0)** | **-5.0** | **1.0** |
| Control (Out of 16) | (-3.0, 2.0) | -1.0 | 1.0 | (-2.0, 3.0) | 1.0 | 1.0 | (-2.0, 2.0) | 0.0 | 1.0 |
| Total (Out of 56) | (-12.0, 1.0) | -6.0 | 3.0 | (-7.0, 8.0) | 0.0 | 3.0 | (-12.0, 3.0) | -5.0 | 3.0 |

Statistically significant differences were seen for Constancy when comparing Testing Point 1 → Testing Point 2 and Testing Point 1 → Testing Point 3, albeit both negative indicating a decrease in scores. There was a 'difference of means' of -5.0UA for Total Mental Toughness suggesting the BAS2 cohort had a reduced level of Total Mental Toughness by the end of the season when compared to pre-season. This was not significant because the 95% CI shows they could have scores 12UA less to 3UA more for Total. It might be suggested as the 95% CI is approaching zero, there is a trend towards them having a lower accumulated score at the end of the season.

### 4.4.9 Whole Squad Longitudinal Psychological Measurements Continued

*Table 46: BAS3 Whole Squad Longitudinal Psychological Changes*

| **Output Measures** | **Testing Point 1 → Testing Point 2** | | | **Testing Point 2 → Testing Point 3** | | | **Testing Point 1 → Testing Point 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means | 95% CI | Diff. of Means | SE of Means |
| **Mental Toughness** | | | | | | | | | |
| Confidence (Out of 24) | (-4.0, 4.0) | 0.0 | 1.0 | (-6.0, 1.0) | -2.0 | 1.0 | (-7.0, 1.0) | -3.0 | 2.0 |
| Constancy (Out of 16) | **(-6.0, -2.0)** | **-4.0** | **1.0** | (-3.0, 2.0) | 0.0 | 1.0 | **(-7.0, -2.0)** | **-4.0** | **1.0** |
| Control (Out of 16) | (-3.0, 2.0) | 0.0 | 1.0 | (-3.0, 2.0) | -1.0 | 1.0 | (-4.0, 2.0) | -1.0 | 1.0 |
| Total (Out of 56) | (-12.0, 3.0) | -5.0 | 3.0 | (-10.0, 3.0) | -3.0 | 3.0 | **(-16.0, -0.0)** | **-8.0** | **3.0** |

Statistically significant differences were seen for Constancy when comparing Testing Point 1 → Testing Point 2 and Testing Point 1 → Testing Point 3, albeit both negative indicating a decrease in scores. Alongside this, a negative significant difference was evident for Total Mental Toughness across the competitive season. There was a 'difference of means' of -3.0UA for Confidence from Testing Point 1 → Testing Point 3 suggesting that the BAS3 cohort had lower levels of Confidence by the end of the season. This was not significant as the 95% CI suggests they could have scored anywhere between 7.0UA less to 1.0UA more. It might be suggested as the 95% CI approaches zero, there is a trend towards being significant.

### 4.4.9 Whole Squad Longitudinal Psychological Measurements Continued

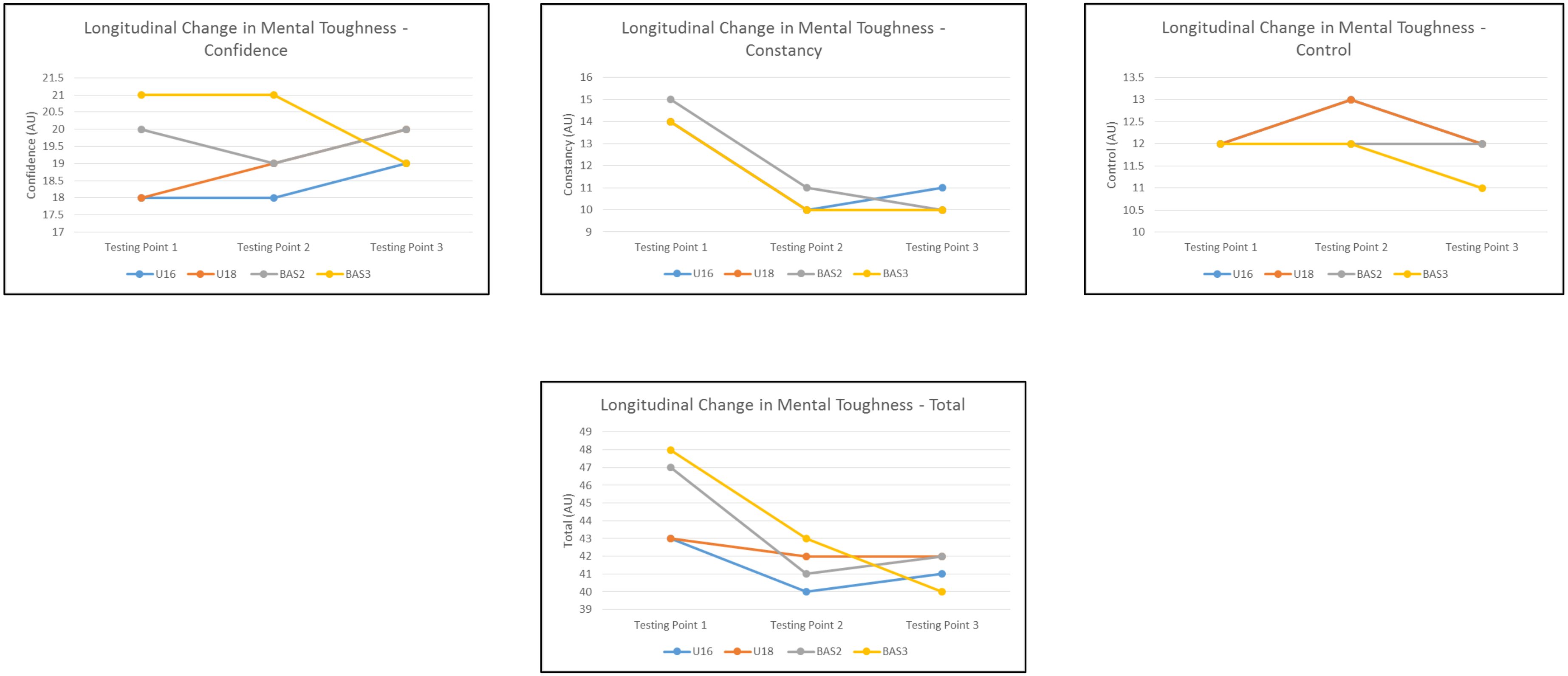



*Figure 11a-d: Line graphs highlighting the longitudinal change for different age categories for all psychological outcome measures*

## 5. DISCUSSION

From the analysed data, there were fewer anthropometric, physiological and psychological differences between the age groups than originally hypothesised. However, clear differences were seen for anthropometric outcome measures (body mass and fat free mass) and physiological outcome measures (lower body power and strength) across age group comparisons with the majority being in the favour of the older cohort. The longitudinal data, when analysed identified fewer differences than the researcher initially hypothesised. One of the main longitudinal findings was identified for the BAS3 psychological outcome measure, Total Mental Toughness, where data recorded at the end of the season (Testing Point 3) was statistically significantly lower than at the pre-season (Testing Point 1).

Rugby Union is an established and well developed sport; however, it only turned professional in 1995. Since this change, teams have strived to gain any physical or psychological advantage over their opposition. This has produced an interest to attain large increases in average anthropometric and performance measures. Evidence from literature, which supports this theory, suggests that body mass has increased, not just since the turn of professionalism but over the last four decades (Lombard, et al., 2015; Norton & Olds, 2001; Olds, 2001). This increase in general player body mass can be attributed to changes in the demands of Rugby Union (Quarrie & Hopkins, 2007) and nutrition (Tarnopolsky, 2008). Duthie, et al., (2006) and Sedeaud (2012) both reported improvements in fat free mass, while, Garraway (2000) documented improvements in strength, speed and stamina. Other reasons for the increase in body mass could be attributed to change of lifestyle within the population such as improved living standards, living for longer and being more knowledgeable about how to make performance improvements. Despite these relatively rapid changes in body compositions and physical characteristics there are limited accounts relating to Rugby Union within existing literature. Therefore, the aims of this study were to gain a greater understanding of elite youth Rugby Union players in Scotland across four age categories (U16, U18 BAS2 and BAS3). Alongside this, the researcher aimed to investigate longitudinal changes across the four developmental-level categories during a competitive season. Data were categorized by age or playing level documenting the physiological, anthropometric and psychological characteristics.

The findings from the analysis were broken down into two main sections which compared results: across four age groups, at three different time points and each age group across the season. The data produced undertook further, more detailed analysis which focussed on the main performance characteristics and the associated outcome measures.

## 5.1 Across Age Group Comparison

### 5.1.1 Anthropometry

As hypothesized body mass and fat free mass were significantly greater for older athletes compared to younger, especially between the BAS3 v U16 and U18 cohorts. This was apparent at the first two testing points; however, only fat free mass was seen as statistically different at Testing Point 3 or end of season. Despite this, large effect sizes were evident showing vertical improvements as elite youth athletes progressed through the playing levels. This factor is supported by published literature which indicated that increased body mass is important due to larger collisions experienced as age progresses (Sedeaud, 2012). Similarly as hypothesized, body fat percentage would remain similar throughout the season across all age groups. Data from this study showed no significant differences for body fat percentage and few large effect sizes across the different developmental levels. At Testing Point 1, it was evident from descriptive statistics and bar charts that the oldest forwards, BAS3, had a lower body fat percentage compared to the other age groups, albeit no formal analysis was completed for forwards. This trend was also evident for the next two testing points. It was also recognised that at Testing Point 1, the back’s body fat percentages varied between the four age groups; however, similarly to forwards this can only been identified from descriptive statistics, not formal analysis. The forwards portrayed a linear progression of body fat percentages as they progressed through the age groups in that they become leaner and heavier, although no formal analysis was completed due to cohort size. The backs however, did not follow a linear progression and the data is more erratic – non-conclusive. Overall, little difference was identified in the Whole Squad analysis. These findings are in line with current literature where heights, body mass and fat free mass appear to increase with age (Darrall-Jones, et al., 2015). However, when comparing age group data from the current study to the data published by Darrall-Jones, et al., (2015) the U16 groups were very similar for body mass means and standard deviations. Contrary to this, the U18 players from the study published for English youth Rugby Union players indicated that these athletes were considerably heavier, by on average 10kg. It is believed that the lack of change in body fat percentage results from large inter-individual variations within the playing squads (Till, et al., 2014). However, if you consider the effects of maturation rates and level of training these athletes are exposed to, this could be a major factor when carrying out forward comparisons. Another explanation which may account for the minimal change in body fat percentage in Whole Squad analysis could be attributed to the nature of the sport. Rugby Union is a highly collision based sport and possessing a greater level of body fat will aid to 'cushion' the body during these collisions (Morehen, et al., 2015). Although it was not a direct comparison for this study, other studies have shown that forwards tend to have a larger body fat percentage than backs, which is believed to be as a result of forwards traditionally being exposed to more collisions per game (Bell, 1973). However, as the older Academy players are much heavier and have a greater amount of fat free mass than the younger age groups, the similarity in body fat percentage could have detrimental effects on overall physical performance. This 'excess' body fat can affect thermoregulation and have a negative impact on metabolic demand, therefore hindering performance. No significant differences were found in this study which is in agreement with a study published by Mayes &

Nuttall (1995). They found that there was no significant difference in body fat percentage between Senior and Junior Rugby Union players.

### 5.1.2 Functional Movement

The large intra-scorer reliability of R=0.84 (Myer, et al., 2006) was a major contributing factor as to why the Tuck Jump Test was selected. This factor would allow data to be compared to the data collected throughout the season at pre-determined testing points by the Academy coaches. Myer, et al., (2006) also stated that it may be more consistent for a single clinician to reassess performances. Data from this study clearly identified that the only inter-level difference that was evident at the third testing point (end of season) was between the U18 and U16 cohorts. The U18 cohort on average performed the test with a better level of technique. This suggests that at some point between the two testing points they were exposed to training which replicated the jumping mechanics involved, which had a direct effect on the test scores. Myer, et al., (2004) published that tuck jump exercises are a useful tool for coaches and clinicians to identify potential lower body weaknesses during jumping and landing, such as increased valgus strain and side-to-side differences. In conjunction with this, it could be a useful tool to highlight improvements in lower body jumping mechanics which are critical for achieving top level performances in sport. Studies on cadavers, computer modelling and in vivo have demonstarted that valgus loading on the knees increases anterior cruciate ligament (ACL) strain (Markolf, et al., 1995; Lloyd & Buchanan, 2001). Fukuda, et al., (2003) demonstarted that increases in subluxation of the tibia and loading on the ACL can arise from physiologic valgus torque on the knee joint. Alongside this, predicting future ACL injuries was highly associated with valgus forces on the knees. This was documented in a prospective combined biomechanical-epidemiologic study by Hewett, et al., (2005). Therefore, it is reasonable to assume that using the Tuck Jump Test on young athletes contributes to a reduction of future ACL injury risk by indentifying potential weaknesses during landing and jumping mechanics. Recorded data would allow coaches to implement an appropriate intervention programme.

### 5.1.3 Lower Body Power

Whole Squad analysis indicated that the older cohorts, BAS2 and BAS3, jumped significantly higher and had a large effect size compared to the younger cohorts. These findings are consistent with studies published globally (Darrall-Jones, et al., 2015). In line with published data for U16 and U18 CMJ scores, English youth players on average jumped higher than the Scottish players who participated in this study. The U16 Scottish athletes jumped 29.4±3.9 cm whereas, the English U16's jumped 33.5±4.8 cm. Similarly, the English U18 players jumped higher than their Scottish U18 counterparts, 39.5±6.1 cm compared to 35.7±3.1 cm. It should be recognised that despite the studies agreeing that the progress across the age groups is very similar, differences between the Scottish and English players were evident. Current literature suggests that changes in jump height across age categories is as a result of physiological adaptations which occur during maturation (Darrall-Jones, et al., 2015). Alongside this, more complex training programmes with power work incorporated and greater absolute strength allows for differences in maximal power output measured from the CMJ to be produced. Maximal strength and power output are well documented with increased absolute strength having a positive correlation to power output (Baker , 2001; Argus, et al., 2012; Peterson, et al., 2006).

When forwards' means and standard deviations were compared across the age categories it was evident that the older cohorts trended to produce greater power output, expressed, as jump height, although this data were not formally analysed. It is reasonable to assume that the differences in game intensity played, the larger collisions and more powerful contact points are contributory factors. This suggests that, the athletes have to be appropriately prepared physically to play and compete at this level of rugby through undertaking a more intense training programme.

Another contributing factor could be the forces of scrums in elite Rugby Union which can be as great as 6000-9000N, these equate to 600-1000kg of pressure (Quarrie & Wilson, 2000). As the BAS3 players are exposed to game forces greater than the younger players it would be reasonable to assume that this factor contributes to differences in lower body power outputs. Robinson & Mills (2000) reported that the players who were the most forceful scrummagers also recorded higher CMJ scores. However, large variations in literature have been reported, this could be attributed to a number of external factors such as age, gender and/or playing level (Young, 2005). Previous studies have indicated that in tests lasting approximately thirty seconds, players who produce more force will fatigue at a faster rate than those who produce lower forces (Cheetham, et al., 1988).

### 5.1.4 Strength

Published strength data are currently very limited for Rugby Union youth players; however it is important for comparison reasons. Highlighted in a recent publication it was reported that absolute strength has been linked to performance regardless of position (Fuller, et al., 2013). For example, Smart, et al., (2014) stated that absolute strength is strongly correlated to the number of turnovers during a game. Darrell-Jones et al., (2015) first documented youth strength data for Northern Hemisphere players and made a direct comparison between U18 and U21 players. The author believes that prior to this, Argus et al., (2012) provided the only data available for 16-21 year old Rugby Union players.

Power and strength have been highlighted as the characteristics which are vital for Rugby Union players, especially the forwards. These characteristics are seen as a vital components of a player's make-up if they are to compete successfully within the sport which has a large number of forceful collisions (Lander & Webb, 1983). Strength is one's ability to move a weight over an extended period of time whereas power is the velocity in which a weight is moved. Although it is well recognised that there is a body of opinion which has stated that Rugby Union is determined by large powerful collisions therefore there is a need to possess absolute strength. Absolute strength is a vital aspect of set play and specific positions. Nowhere is this more obvious than in the completion of scrums where props in particular are exposed to massive loads. The slow concentric contractions exerted when lifting maximal weights exposes a player to the potential demands required during scrums and mauls (Hazeldine & McNab, 1991). Baker (2002) stated that professional Rugby League players had a larger maximal upper body strength lift when compared to their younger counterparts which is in agreement with the current findings of this study.

It was hypothesized, by the author of this study that absolute strength scores would be significantly greater as the players progressed through the regional pathway. The findings confirmed this with the majority of 3RM Squat and 3RM Bench absolute lifts that were analysed. This progression was not only identified but confirmed when looking at absolute strength but was also apparent when this data was scaled allometrically. This was carried out in an attempt to gain a better understanding of strength. These findings for absolute strength scores agree with current literature from studies that were carried out in Rugby Union (Argus, et al., 2012; Darrall-Jones, et al., 2015) and Rugby League (Baker, 2002; Baker , 2001; Till, et al., 2014; Till, et al., 2014). The Argus study compared different playing levels e.g. Professional, Semi-Professional, Academy and High School New Zealand based Rugby Union athletes. From this study the data collected for the Academy and High School athletes were at an equivalent level both in average age and known training stage. This factor allows them to be compared to the BAS2 and U16 players in this study. From the results, this study predicted One Repetition Maximums (1RM) from different sub-maximal lifts using the following formula: (100*weight lifted) / (101.3-(2.67123*repetitions)). The results were as follows for Academy and High School maximal predicted Squat: 151±30 kg and 100±19 kg respectively.

For the purpose of this comparison, when the 3RM Squat data from the current study was used to predict 1RM Squat data, scores would be as follows: U16 104.0±17.0 kg and BAS2 164.4±36.9 kg. This would suggest that for predicted 1RM lower body absolute strength data, the athletes from this study were stronger than those who participated in the other studies. Whereas, when 3RM Bench data were compared it was apparent that only the BAS2 athletes were stronger. The U16 results produced in this study indicated that their upper body strength was much lower, on average 26kg, than the High School athletes in New Zealand. The more recent Darrall-Jones study on English Rugby Union athletes, measured 3RM as their strength marker. From their study the U18 Bench 3RM was 82.6±10.8 kg, 3RM Chin 12.3±6.9 kg and 3RM Chin 101.0±13.2 kg. Comparing all these measurements to U18 athletes in the current study, 3RM Bench and Chin scores were lower compared to the English players. Despite showing the same trends when age groups were compared, the absolute strength data for the U18 players in this study were lower compared to those tested in the Darrall-Jones paper. However, when comparing data to the Argus paper, athletes from this study were comparable if not stronger within their age groups. Data published by Till et al., (2014) compared youth forwards and backs as they progressed through the age groups from U16 to U20. Data collected for absolute strength were attained for 1RM, to make it possible to compare the age groups directly. Predicted 1RM scores have been calculated on data from this study which allows comparisons to be made. The data shows that U16 forwards and backs from this study were stronger for absolute strength. The backs from this study were similar for 3RM Bench but much stronger for 3RM Squat. However, it has to be noted that these comparisons were completed with descriptive statistics and not formal analysis due to small sample sizes.

When 3RM Squat and 3RM Bench absolute strength scores were scaled allometrically a clear linear progression was obvious at almost every time point of testing. Allometric scaling was included as a measurement due to the fact that, the more common, isometric or relative scaling has been questioned as a method of comparison as it does not remove the possible influences of body mass. (Batterham & George, 1997). In a study by Jacobson, et al., (2013) exploring isometric and allometric scaling as methods for normalizing strength data in elite American football athletes, it was found that typically the heavier players had greater absolute strength scores. Combined with this, when the data were scaled isometrically or relatively then it was the lighter players who were deemed as 'stronger'. When the data were scaled allometrically there appeared to be no significant differences between the players regardless of body mass. In contrast to this, data from the current study showed a clear linear progression for absolute and allometric squat and bench strength scores. This could be attributed for by a similar linear development in body mass and fat free mass by all groups within the study.

These overall findings suggest that a clear progression exists for strength performance measures within a Rugby Union pathway. It is crucial that these strength gains are recognised as a vital component, which the players should adhere to, as they progress to senior rugby. It has been documented that the intense nature of adult Rugby Union training schedules can be a limiting factor in potential strength development (Baker, 2001; Baker, 2013).

### 5.1.5 Speed

Duthie, et al., (2003) wrote a succint statement that suggested that a player's ability to move quickly and effectively during field based high intensity intermittent team sports is crucial. This ability provides players with the opportunity to outmanouevre their opposition and exploit gaps in their defences. The reason 10m and 30m distances were chosen for this study was to allow comparison to data published by Docherty, et al., (1988) which recorded that the majority of sprint distances during a match were completed over 10-20m, 15% over 20-30m and a very small percentage over 40m. More recently, Austin, et al., (2011) published data illustrating percentages of matches spent running in certain distance bandings. The study concluded that over 50% of the sprints during a match covered distances shorter than 20m and a small percentage achieving over 40m; this is compounded by the 1988 Docherty study. Data from this study show no significant differences for 10m sprint times across all comparisons; however, large ES were present for several comparisons, favouring the older cohorts. These findings align with current literature where no significant differences in speed times were seen between age categories (Darrall-Jones, et al., 2015; Gabbett, 2002; Gabbett, 2009; Gabbett, et al., 2008). Although these papers agree with the current study's findings; a comparison of the current data showed differences in testing scores. Analysis of 10m sprint times for U16 and U18 players within an Academy programme, indicated that the U16 athletes showed similarities. However, U18 Testing Point 1 (Pre-Season) scores in this study were faster over 10m than their English counterparts: 1.73±0.07 s vs 1.81±0.06 s. A possible reason for this could be attributed to the differences in body mass of the groups with the English athletes being, on average, 10kg heavier. This factor may account for, this 'loss' of speed as their body characteristics may not transfer well to short, explosive sprints. Contradictory to current literature, significant differences were evident at Testing Point1 and 2 within this study where the U16 cohort recorded times which were significantly slower than the BAS3 cohort and interestingly the U18, respectively for Whole Squad analysis. Published literature has reported that momentum, not speed, is a more accurate way to discriminate between age categories (Till, et al., 2014) and playing level (Baker & Newton, 2008; Barr, et al., 2014). To address this area 10m Momentum was recorded from 10m Sprint times. This is due to the high percentage of plays which occur in Rugby Union require a large amount of force in close proximity to the opposition. Data from this study clearly highlights a progression at all three of the testing points for Whole Squad data. Significant differences were evident at Testing Points 1 and 2 between both the younger age categories, U16 and U18, and the oldest age group, BAS3, in the pathway. Although 10m sprint times showed virtually no difference at all it was evident that the significantly larger body masses of the older players allowed for more momentum to be produced.

### 5.1.6 Aerobic Fitness

Aerobic fitness is an area that has been debated in literature as to whether it is a major factor in Rugby Union (McLean, 1993). A study completed by Reid & Williams (1974) did suggest that a players $\dot{V}O_2max$ is an ideal indicator of aerobic fitness for Rugby Union players. The reasons for debate arises from comparisons made with other team based sports. Elite football (Williams, et al., 1973) and Australian Rules players have $\dot{V}O_2max$ scores over 60 ml/kg/min, in comparison to Welsh Rugby Union players whose scores only reached 53.3 ml/kg/min (Cunniffe, et al., 2009). The reason for this lower aerobic capacity compared to other team sports, may be attributed to the number of stoppages and extended restarts which allow players to recover resulting in reduced need for a higher $\dot{V}O_2max$. However, the modern style of Rugby Union has resulted in a faster, free flowing game where teams look to keep the ball 'alive' and build consecutive phases. This has also resulted in the current game having prolonged periods of play with a reduced recovery time due to a fewer number of stoppages. With these game changes, an increase in aerobic capacity would be expected and $\dot{V}O_2max$ scores definitely need to be considered in a light of contemporary match play. Previous literature has shown that no significant differences were seen for aerobic fitness across age categories for the YoYo IRT-1 (Darrall-Jones, et al., 2015; Gabbett, 2002; Gabbett, et al., 2008; Gabbett, 2009). Comparing data from the Darrall-Jones paper, which looked at English Academy players, the U16 athletes ran a similar distance. The U18 players from this study ran approximately 200m further, equating to 5 levels on the YoYo IRT-1, on average, compared to their English counterparts. It has to be noted that distances were calculated from the score sheet in Appendix 8.5. Similarly to maximal speed, the smaller body frames of the Scottish U18 athletes are better equipped to meet the demands of the YoYo IRT-1 due to the repetitive turns. Although the three Gabbett studies were in Rugby League, which, despite a slightly different game system and rulings, it is similar to Rugby Union. Results from the present study agree almost completely with the findings published by Gabbett. A significant difference was evident between the U16 and BAS3 cohorts at Testing Point 1. This could be attributed to the fact that the U16 cohorts had started their pathway programme a few months prior to this testing point whereas the BAS3 players have been exposed to an extensive training history. Although not statistically significantly different, large ES occured between the BAS2 and U16 cohorts for YoYo IRT-1 predicted $\dot{V}O_2max$. YoYo IRT-1 predicted $\dot{V}O_2max$ was chosen as it has been reported as having high validity, and correlates well with direct measures of $\dot{V}O_2max$ (R=0.7) (Bangsbro, et al., 2008). In line with most field based testing, this method has received criticism as athletes with similar $\dot{V}O_2max$ (53ml/kg/min) varied in YoYo IRT-1 distance by roughly 1000m. The potential explanation for this would be the way in which these tests are conducted. A direct measure usually consists of running on a treadmill with increasing speed or incline until volitional exhaustion. Whereas, the YoYo IRT-1 contains many accelerations, decelerations and turns causing a different physiological demand on the body. Although a large r-value, the YoYo IRT-1 is currently recognised as one of the best field based measures for aerobic fitness as the test process includes similar characteristics to field based sports. Data from Testing Points 2 and 3 identified only moderate to large ES between age categories which agrees with current literature. This clearly shows that the older groups were not completing significantly more levels (or distance) on average than the younger athletes. Atkins (2006) identified very little difference in running distance between professional and semi-professional Rugby League athletes. The significant difference in fat free mass and body mass between the age categories in the current study, suggest that the heavier, olders players have a better running capacity. This suggestion would be expected by a large direct measure of $\dot{V}O_2max$ that were produced before being corrected for body mass.

### 5.1.7 Anaerobic Fitness

Published literature shows that on average, forwards sprint 16 times per game whereas backs sprint 23 times per game (Roberts, et al., 2008). These sprints will occur between other phases of fatigue-inducing play such as tackles, rucks and defensive resets. A player's ability to repeat near maximal sprint efforts at any moment is crucial for team-based sports like Rugby Union. Work in New Zealand rugby by Quarrie, et al., in 1995 and 1996, found that elite players fatigued significantly less quickly compared to semi-elite players (reduced percentage Decrement in RSA). In an unpublished work by Urquhart, et al., (2016), the opposite was seen, elite Rugby Union players (professional) were found to fatigue quicker than their junior Academy counterparts. Data from this study shows no significant differences for percentage decrement in the RSA test. However, the BAS3 cohort as a whole, has the lowest average percentage decrement compared to the younger cohorts, agreeing with the findings from the Quarrie studies. Descriptive statistics of forwards and backs data highlighted that the backs' times from Testing Point 3 identified differences in percentage decrement in favour of the younger players. This could be attributed to the smaller lighter frames of the younger players or potentially the seasonal fatigue that the older players experienced, affecting testing abilities. However, due to sample sizes this assumption was based purely off descriptive statistics. RSA was an appropriate test to assess fatigue resistance as explained by Fitzsimmons, et al., (1993) whose study showed that a RSA test mimics the nature of field based intermittent sports. More recent published work confirms the importance of 'fatigue resistance' or greater levels of anaerobic fitness in field based sports. Fuller, et al., (2007) stated that in the modern game teams are expected to be involved in a large amount of tackles in one game (>100), with the majority of these being made by the forwards (van Rooyen, et al., 2008). In order to perform these tackles competitively and carry out other aspects of the game; rucks, mauls and scrums alongside effective execution of lifting at lineouts to compete with opposition (Gamble, 2004) a high aerobic capacity and the ability to recover quickly after periods of linked play was necessary.  All these factors combined highlight the importance of being ‘fatigue resistant’ in order to have an advantage over the opposition.

### 5.1.8 Agility

Due to low numbers of participants completing the 505 Agility test, statistical analysis was not possible with every group at each testing point.  With the various number of agility tests completed in published literature comparisons are difficult.  From data published on elite English youth Rugby Union players it was concluded that the older age categories had faster times for the 505 Agility test (Darrall-Jones, et al., 2015).  When comparing data collected from this study (from Testing Point 1) to the Darrall-Jones paper it was evident that the U18 players performed the test faster off both feet compared to the English U18s.  However, the U16 players from this study performed slower off both feet compared to their English counterparts for the 505 Agility test.  Significant differences and large ES were evident in the majority of possible comparisons, which concurs with the current literature.  This indicates that as the athletes’ progress through the Academy programmes, not just in Scotland, they become faster for change of direction drills.  This is extremely relevant for Rugby Union as it will provide the players with the ability to create opportunities in attack, evade defenders, find or create spaces during play.

### 5.1.9 Mental Toughness

As previously mentioned, the SMTQ provides a global measure of Mental Toughness.  The three subcategories all provide a different measure of a participants ability to perform.  Control refers to a players’ ability to appraise a stressful situation as less stressful and exert their own emotion onto that event.  Constancy is the determination, personal responsibility and unrelenting attitude allowing the athlete to concentrate at the task in hand (Sheard, et al., 2009).  Finally, Confidence is the athletes’ belief in their own abilities and to be better than any opponent they come up against (Sheard, 2010).

There is a current lack of psychological data present in youth Rugby Union which means that it is difficult to compare the results of this study with that of other psychological literature. From the current study there was only one compariosn which resulted in a statistically significant difference. This was for Confidence between the BAS3 and U16 cohorts at Testing Point 2, in favour of the older cohort. For cross-level comparions the only sub catergory of Mental Toughness which favoured the younger cohort, compared to an older, was Control. This result is surpising as Control is the ability to appraise a stressful situation and not allow their own emotions affect the outcome of that specific situation. The time point at which this was collected was when contract negotiations were happening and it maybe that the BAS3 players felt low Control whilst discussions about their futures were not entirely in their own hands (no Control).

The scores per category (Control, Constancy and Confidence) for each age group are moderate allowing scope for improvement for these scores. In a published study by Bell, et al., (2013) found that a 2-year psychological intervention demonstrated significant improvements in mental toughness. Increasing an athlete’s mental toughness has been seen in other sports and has had a positive impact on performance by allowing these athletes to better regulate emotions during stressful situations (Gucciardi & Jones, 2012; Mahoney, et al., 2014).

## 5.2 Longitudinal Age Group Changes

To the author's current knowledge this is one of the first studies to investigate changes in performance characteristics within different playing levels across a playing season. The author believed it was inappropriate to compare data collected in this study to other field based sports, apart from Rugby League. This decision was based on the different demands and styles of training and games resulting in sport specific adaptations. It was hypothesized that the greatest improvements across the season would be seen in the younger age groups due to their relatively short training history, previous experience and exposure within the sport.

### 5.2.1 Anthropometry

Although not significant, from the start to the end of the season, positive 'difference of means' were evident in almost all anthropometric outcome measures, suggesting greater body mass, BF (%) and FFM for all four cohorts. The only outcome measure which did not show any increase throughout the season was fat free mass for the BAS2 players. The increased body mass is in line with current literature (Till, et al., 2014). Increases in body fat percentage for all age cohorts contradicts previous studies where seasonal changes in sum of skinfolds for U18 players reduced by 8.2% and 10.1%, (Till, et al., 2014; Gabbett, 2005) respectively. This increase in body mass is likely to be as a result of adaptations related to growth and maturation which occur during adolescence (Malina, et al., 2004). In combination with this, large standard deviations and 95% CI suggest large intra-playing level variation for body mass, FFM and BF (%). Therefore, as a result of these findings, anthropometric measures should be monitored by strength and conditioning coaches throughout the season to ensure the appropriate training programmes and nutritional advice are put in place, which are specific to individual needs. This will help to develop fat free mass which is required as they progress through playing levels to cope with the increase in demands of the game (Gabbett, et al., 2008; Meir, et al., 2001). This current study identified the period from mid-season to end of season as the period where the data either increased or trended towards an increase in the majority of outcome measures for all playing levels.

### 5.2.2 Functional Movement

Currently to the researcher's knowledge there has not been a study which has researched the seasonal change using a functional movement test. Results from this study indicated that over the course of the season some improvements were evident. Cross seasonal data showed that the U16 cohort was the only cohort to improve significantly between Testing Points 1 and 2; however significantly lower than their starting level. This infers that a clear pattern of improvement is not present across the age groups. The Tuck Jump Test, recognised as a reliable method for identifying poor jumping and landing mechanics, is a useful tool in potentially reducing the risk of ACL injuries by identifying weaknesses (Myer, et al., 2008). A study published in 2005 attempting to reduce the number of ACL injuries in female football, stated that a neuromuscular training programme may have a positive effect on reducing ACL injuries. Although this study was looking at female athletes, who have a higher risk of ACL injuries than males as a result of difference in Q angle, it clearly showed that an intervention replacing the 'traditional' warm up, with an alternative, consisting of education, stretching, strengthening, plyometric and sport-specific games reduced the risk of ACL injuries (Mandelbaum, et al., 2005). It is less likely for males to have an ACL injury than females; however, reducing the risk would be extremely beneficial to young athletes.

### 5.2.3 Lower Body Power

Current literature states that the younger age groups demonstrated a much greater improvement and that the older groups struggled to improve across a season. A reason for this lack of improvement could be attributed to the physicality of the game the older players are exposed to, resulting in heavier contacts, collisions and forces creating fatigue and the necessary requirement for a longer recovery period. This study disagrees with testing from the Till, et al., (2014) study, who tested

Standing Long Jump and found greater improvements in the younger groups. Whereas, CMJ or vertical jump data from the current study saw the BAS3 cohort trending towards significance with a 'difference of means' of 8.4cm across the season. This may be explained by different training programmes or better specific technique used when completing the CMJ. It is reasonable to assume that all groups must have increased absolute power due to the increases in body mass across the season.

### 5.2.4 Strength

Findings from current literature state that U18 and U20 Rugby League players made significant improvements in squat and prone row from the start to end of season. In a study carried out by Till, et al., (2014) it was only the U18 players who significantly increased in bench. These findings are similar to findings from this study, where the U16, U18 and BAS3 cohorts trended towards improvements in absolute strengths scores where enough data was collected. The only outcome measure where a statistically significant difference occurred was for the U16 cohort for 3RM Bench where they improved anywhere between 2.0kg to 16.7kg, across the season. When directly comparing the change in average scores from pre-season testing to post-season testing with the Till study from 2014, it suggested that the U18 squat data were higher than the current study. The English Academy athletes from the Till study averaged a change in 1RM scores of 16.4kg, increasing from 118.4±23.8 kg to 134.8±19.5 kg. Whereas, changes in the 3RM score for the Scottish athletes in this study was 9.1kg: 112.2±21.1 kg to 121.3±20.1 kg. When the 3RM data were calculated to predict a 1RM, the change was 7kg, increasing from 120kg pre-season to 127kg post season. The average score was still lower, when converted to 1RM, than the English U18 players. Similarly to the bench data the English U18 players had a bigger change in 1RM scores, lifting much heavier than the U18 athletes from this study. No 3RM Squat data was available for BAS2 Whole Squad players, however, average 3RM Chin absolute scores decreased by 8.7kg for the BAS2 cohort, although not statistically significant. This cannot be attributed to changes in body mass as this cohort's average body mass increased by 0.6kg across the season. Comparison to current literature is difficult for absolute 3RM Chin data as many of the published studies have used the prone row as an alternative measure.

### 5.2.5 Speed

This study was in agreement with current literature which concluded that very small or no improvements in 10m or 20m speed times were evident for U14 and U16 Rugby League players. Whereas, older players (U18 and U20) showed, significant longitudinal improvements in speed times. Findings from the current study showed that the U16 and U18 playing levels, on average, ran slower over 10m and 30m from pre-season to the end of season – albeit this was not statistically significant. It should be reasonable to assume that the increase in average body mass, training and playing was a resultant factor for this. The BAS3 cohort trended towards an improvement in both 10m and 30m sprint times indicated by a negative 'difference of means', whereas, the BAS2 cohort only trended towards an improvement in 30m sprint times. Despite a positive 'difference of means' for 10m sprint time for the BAS2 cohort, indicating a slower average performance at Testing Point 3, it could be significant during a match where a player directly competes with an opponent. Till, et al., (2014) found that 10m Momentum increased significantly in all age groups across a season. The present study only identified slight trends towards improvement in 10m Momentum for the U16, U18 and BAS3 playing levels. An *unexpected* decrease for the BAS2 cohort is likely to be attributed to an average increase in body mass of 0.6kg. Another factor for consideration is that the 10m sprint times were slower on average due to the effects of fatigue and injuries which occurred during the competitive playing season. It is reasonable to assume that positive changes in speed may not be evident until anthropometric data starts to plateau with age. Regardless of this, practitioners should continue to develop speed and plyometric ability throughout the season in light of the reported importance of these factors. In conjunction with this, momentum should be considered and a method of measuring improvement, within sports such as Rugby Union and Rugby League (Baker & Newton, 2008). From previous investigations it has been suggested that momentum may be a more important performance measure to monitor in younger athletes to ensure progression (Till, et al., 2014; Baker & Newton, 2008).

### 5.2.6 Aerobic Fitness

Current literature indicates that older players improve in aerobic fitness tests throughout a season with 46.1% improvements seen in distance for U20 players. Alongside this, it was concluded that younger players showed negligible changes (Till, et al., 2014). This contradicts findings from the current study which identified that the older cohort's average Predicted $\dot{V}O_2max$ trended towards a reduction in YoYo IRT-1 testing with the average distances for the BAS2 and BAS3 cohorts being 307m and 175m less than at pre- season, respectively. These distances were estimated from the Predicted $\dot{V}O_2max$ score sheet found in Appendix 8.5. A reason for this drop in performance could be attributed to the higher standard of game played, a potential fatigue effect associated with a long season or an increased training effect seen in the younger players. A previous lack of exposure to training, potentially gives the younger athletes more headroom for greater improvements with large differences in performance when exposed to higher levels of training. Comparing these data to similar Australian Rugby League studies, it agreed with data found for U18 players who had a positive seasonal increase in estimated $\dot{V}O_2max$ (Gabbett, 2005). Predicted $\dot{V}O_2max$ data for U18 players were also comparable to previous Rugby League studies. Pre-season data (Testing Point 1) from this study was 48.7±4.9 ml/kg/min for the U18 cohort was higher than the 2014 Till, et al., study which published aerobic fitness scores of 46.6±2.8 ml/kg/min, but lower than data published by Gabbett (2006) who recorded predicted $\dot{V}O_2max$ scores of 50.6 ml/kg/min. The present findings are slightly unexpected as it was hypothesised that aerobic fitness would improve with playing level due to the increase in training intensity and match demands (Gabbett, 2012).

In a study by Lombard, et al., (2015) it was found that aerobic fitness never improved significantly when studying thirteen years worth of U20 data.

### 5.2.7 Anaerobic Fitness

Longitudinal change for anaerobic fitness measures from this study showed minimal improvements across the age groups. Data from the descriptive statistics, not formal analysis, highlights that the forwards showed no improvements throughout the season. It is reasonable to assume that this was due to a different focus during training sessions for forwards, for example increasing strength or improving technique for scrummaging were prioritised which limited time that could be spent on anaerobic fitness. Traditional straight line anaerobic endurance training and situational/sports specific methods, produced improvements in anaerobic fitness levels. However, the sports specific methods returned better rewards in improving anaerobic fitness via the 300 yard shuttle run test (Sporis, et al., 2008). As previously stated, anaerobic fitness was not a primary training focus; however, the sport specific demands of Rugby Union, especially for the backs, has to be a factor. Longer and more frequent sprints has led to improvements in backs when compared to forwards; albeit this is from descriptive statistics and not formal analysis due to sample size.

### 5.2.8 Agility

There is currently limited available literature on the longitudinal change in Rugby Union players' agility ability. Data from this study suggests improvements or trends towards improvement for the U16, U18 and BAS2 cohorts turning off both feet indicated from negative 'difference of means' between Testing Point 1 and Testing Point 3. The only group to show a statistically significant improvement was the U16 cohort between Testing Point 2 and 3. The cohort on average performed 0.15s faster turning off the right foot, and turning off the left foot 505 Agility times approached significance. Caldwell & Peters (2009) studied the seasonal variation in physiological fitness in a semi-professional football team and found that the seasonal change in agility, using the Illinois agility test, remained constant i.e. no change over the season. Previous research has stated that the use of small side games, on a restricted pitch area during training, especially in football, requires a large amount of changes in direction to evade and outmanouvre opponents where required. Subsequently this factor would lead to an improvement in agility performance during testing (Mercer, et al., 1997). Similarly to anaerobic fitness, participants in this study did not have an emphasis on agility performance within their training programme. However, the nature of Rugby Union and the general training for the sport which includes small sided games, has led to an improvement in agility performance throughout the season.

### 5.2.9 Mental Toughness

There is a recurring theme in the debate over mental toughness which is whether an individual is born 'mentally tough' (nature) or can the individual be moulded by nurture and become 'mentally tough' (Crust, 2007). Some believe that it is a combination of both nature and nurture which shape an individual's development (Gottesman & Hanson, 2005). Others have debated whether 'mental toughness' is fixed or whether it can be changed. Hardy, et al., (2014) stated that mental toughness is a "relatively stable dispositional trait". In opposition to this Harmison (2011) and Gucciardi, et al., (2015) suggested it was "state-like and open to change or development".

Data from this study shows that there are clear trends towards reduction in average Total Mental Toughness scores for all age groups when analysed as a whole group over the season. When looking more closely at the BAS3 Whole Squad data, Total Mental Toughness is significantly lower than it was at the start of the year, suggesting the state-like nature of mental toughness is applicable. From the BAS3 data it showed a trend towards a reduction in their measured 'Control' which could be attributed to a result of selection or non-selection for National Youth squads or up and coming discussion over professional contracts and futures. All age group cohorts had a similar trend throughout the season. Statistically significant differences were seen between Testing Point 1 → Testing Point 2 and Testing Point 1 → Testing Point 3 for the subcategory Constancy, for all four of the age groups. As previously reported, Constancy is the determination, personal responsibility and unrelenting attitude allowing the athlete to concentrate on the task in hand (Sheard, et al., 2009). This clearly shows that as the season progresses players are displaying a reduction in these factors. This could potentially lead to reduction in performances affecting the selection process. These significant reductions could be attributed to mental fatigue as a result of the length of season.

Current literature studying the effectiveness of interventions has created evidence to support the use of psychological skills training amoung adolescent athletes (Bell, et al., 2013; Gucciardi, et al., 2009). More specifically Sheard & Golby (2006) concluded that a seven week mental skills intervention programme increased performance and self-related mental toughness in adolescent swimmers competing at a high level. The intervention consisted of goal setting, visualistaion, relaxation, concentration and thought stopping skills. The current study identifies there is scope for improvement in mental toughness in Scottish Rugby Union youth players.

## 5.3 Strengths and Weaknesses

The current study is one of the first to investigate the anthropometric, physiological *and* psychological characteristics of elite youth Rugby Union players. The comprehensive battery of tests carried out allows for a greater understanding of the performance profiles of the young athletes who are part of an elite youth performance pathway. Testing on three occasions, at set time points in one season allowed for analysis to be made which identified the within-cohort changes and how elite youth Rugby Union athletes developed across a demanding, competitive playing season. A major strength of this study was the inclusion of psychological characteristics of mental toughness across the Academy pathway. This is a concept which is not clearly understood or perhaps misused in sport and through collecting data on it will help to incorporate a greater emphasis on the importance of mental skills training for athletes. This will be vital in maintaining a positive mental attitude for these young players during potential periods of adversity and pressure e.g. when missing out on selection or when injured. Other strengths of this study, were that it tested and compared a number of playing levels and the number of subjects within the cohorts, ensuring the validity of results and findings. This procedure provided a deeper level of analysis by comparing data between whole groups. This allowed for a vertical pathway progression through youth age groups to be documented.

Another strength of the study was that the coaches were able to monitor the attendance and engagement of their athletes towards the testing programme, ensuring that the players were committed to the process. This study identified time points that highlighted improvements or lack of them, in physical and mental characteristics which in turn would allow coaches to set targets to be achieved throughout the season. This factor provides information that will allow the opportunity for coaches to provide for individual and group goal setting and ensure their athletes are not only trained appropriately but understand how the process will maximise their potential for their specific position and role within the team. Due to their validity, the selection of tests chosen and the protocols selected, ensured that that comparisons could be made with current literature. The test conditions, locations and time of day were all kept constant throughout the season which increased the quality and reliability of the measurements and allowed for direct testing point comparisons. As the athletes are part of an elite pathway and Academy system they were all likeminded individuals who knew the coaches and researchers. This allowed for familiarity, respect and compliance to the tests. Finally, as the researcher has been involved within the sport for many years as a player and coach at various levels, his experience has been invaluable in the design of the methodology of this thesis. His experience allowed for a strong empathy between the researcher and the participants involved in this study.

There were many external factors which affected the study, many being outwith the control of the lead researcher. Obvious external factors included injuries and illnesses, education and family commitments during testing times, and loadings out with set pathway sessions. These included school training sessions and additional weight sessions or training for other sports the athlete might be involved in. In addition to these external commitments, the demands of the playing season could impact on the athletes and consequently not present a 'full' understanding of where each age group truly is. Another weakness of this study was that it had no control group for comparison which means that it is unknown whether some of the performance improvements were due to the specific training programmes put in place or whether they were adaptations related to growth and maturation. Another weakness was the availability of facilities to perform the testing, especially for RSA which was carried out on both an indoor and outdoor artifical 4G pitch. However, despite the difference in testing conditions the researcher believes this had no direct effect on scores due to the outdoor testing only being carried out when the weather was calm and the pitch dry. Finally, not having data collected at each time point, for some of the outcome measures due to external factors, did not allow for a full comparison of data throughout the playing season and age groups.

## 5.4 Practical Implications and Future Research

The author unreservedly believes that this study provides a greater understanding of the development of elite youth athletes as it presents comparative data for a full pathway of Rugby Union players in Scotland. From these, data targets can be set for different time points within a competitive season or for progression to the age group above, as previously explained. The information collated will allow practitioners to assign programmes which will aid the progression of an individual's athletic performance by targeting weaker characteristics rather than just presenting a generic training programme for all athletes. Consideration should be given to training age, injury status and working with a different pool of players when setting programmes and targets. This study has also identified where the different age groups' strengths and weaknesses are and how these can be utilised appropriately by coaching staff to maximise performance. It is important that coaches and practitioners 'know' their athletes and are aware of specific individual strengths and weaknesses to ensure that they provide for the athlete's requirements.

Ideally, a vertical profile of a professional pathway, through all age groups from U16 to professional level, would be created by incorporating professional players in these measurements and the analysis. Alongside including professional athletes, having enough players to allow for a positional split would further enhance the knowledge and depth of the information provided. This would allow the older athletes to have a clear pathway to professionalism with identified check points put in place. This would encourage specific goals and targets to be set by coaches and then achieved by players. If players become more informed as to why programmes exist they can take ownership of their physical development, making them more independent and likely to succeed.

A longitudinal study carried out over an extended number of seasons, would allow for a more accurate understanding and investigation of how an age group progresses over multiple playing seasons or through an age-grade programme. This would be achieved by following the same age groups over a number of years, identifying specific changes for a pool of players. A study of this nature would provide knowledge on where a specific age group, and individual players are in comparison to other age groups at the same stage. A study like this would add value to the programme as the athletes would be followed throughout their development and therefore would more likely to adhere to the testing procedures and more likely to take responsibility for their development.

Finally, a study documenting the maturation status of these elite youth athletes would be beneficial as it would highlight the stage at which athletes will mature and grow. Coaches would be able to identify which athletes will be mentally and physically ready to progress quicker or earlier than others and which athletes may need more attention given to them in terms of development or remediation work on basic skills and principles. This would also allow the studies to analyse the maturation status of the young athletes instead of playing level.

# 6. CONCLUSION

This thesis is a comprehensive within-developmental level and cross-seasonal study of anthropometric, physiological and psychological characteristics of elite youth Rugby Union players. It documents and provides a comparison of cross-level performance characteristics at different time points during a competitive playing season. Alongside this, the study investigated the seasonal changes in performance characteristics that occurred within the different age groups. All data were reported on as Whole Squads to provide an understanding of elite youth Rugby Union playing squads. The vertical pathway progression of these athletes has also been documented in this thesis to identify where the greatest improvements can be achieved.

The current study identified fewer significant differences between the playing levels than had been reasonable to expect. The main variables which the study identified as showing increased results between the different age groups were: body mass; fat free mass; lower body power and absolute strength scores. These results were expected due to the nature and focus of training for Rugby Union and the programmes the athletes undertook throughout the playing season. Some variables analysed did not provide a clear linear progression or significant differences. This position was evident when analysing aerobic fitness and speed data. It was interesting that against expectation, body fat percentage and Total Mental Toughness showed no progression from U16 to BAS3 players. These cross-level data were compared with a paper published by Darrall-Jones, et al., (2015). Darrall-Jones's investigative report incorporated a similar battery of tests carried out on elite youth English Rugby Union players across similar age group splits. The data comparisons highlighted that for the majority of the tests the English athletes performed better than the Scottish counterparts from this study. Exceptions to the above observation were evident in tests carried out for aerobic fitness and speed, where the comparisons indicated that the English U18's had a lower aerobic capacity and were slower than the Scottish U18 players. Potential factors that may explain the reason for this could be attributed to the English players being on average 10kg heavier and 10cm taller, although height was not reported in this thesis, as these physical characteristics are less suited to the design of the tests. There are potentially many factors which have contributed to the English players being anatomically larger than the Scottish player: there is a larger pool of players in England providing more competition which in turn is likely to produce more athletic and larger athletes. Have the players been in academies for longer than the Scottish athletes? Have they been exposed to training from a younger age? On comparison, the physical advantages in height and body mass that the English players have, appears to be a major factor in giving them a slight advantage (in the majority of tests) over their Scottish counterparts .

The longitudinal results were very suprising as they did not confirm the expectations at the beginning of the study. The results recorded few significant improvements across the variables for Whole Squad analysis. This study highlighted the difficulty of a per protocol analysis due to external factors such as injury, illness or school/extra-curricular activities. To ensure all comparisons can be made it is essential that as many players as possible attended training and testing.

This study will provide the opportunity for coaches to consider the results when planning training which is appropriate to the stage their players are performing. This study also provides information which can assist coaches in identifying areas that require attention and help to create an action plan that addresses them by setting individual aims and targets for their athletes. Comparison of these data with similar age groups from other countries allows for these targets to be designed more specifically by coaches through creating potential anthropometric, physiological and psychological improvements which could lead to performance enhancements. Finally, although not all comparisons were statistically significant, further investigation could confirm the findings of this study by identifing those variables which are biologically different and may affect performances in a practical setting.

This study confirms that a large battery of testing is possible, not just at one time point but at multiple points throughout a season; however, player adherence to training and testing is crucial. It has highlighted that it is important that coaches develop all aspects of performance by prioritising the individual's development needs, especially for Rugby Union where the variety of playing positions and specific demands exist. Player needs have to be individualised and respected to ensure that their specific requirements are developed appropriately, this is in agreement with current literature (Duthie, et al., 2003; Roberts, et al., 2008).

## 7. REFERENCES


Appleby, B., Newton, R. U. & Comrie, P., 2012. Changes in strength over a 2-year period in professional rugby union players. *Journal of Strength and Conditioning Research,* 26(9), pp. 2538-2546.

Argus, C. K., Gill, N. D. & Keogh, J. W., 2012. Characterisation of the differences in strength and power between different levels of competition in rugby union athletes. *Journal of Strength and Conditioning Research,* Volume 23, pp. 2698-2704.

Atkins, S. J., 2006. Performance of the Yo-Yo intermittent recovery test by elite professional and semi-professional rugby league players. *Journal of Strength and Conditioning Research,* 20(1), pp. 222-225.

Austin, D., Gabbett, T. & Jenkins, D., 2011. The physical demands of Super 14 rugby union. *Journal of Science and Medicine in Sport,* 14(3), pp. 259-263.

Baker , D., 2001. Comparison of upper-body strength and power between professional and college-aged rugby league players. *Journal of Strength and Conditioning Research* , Volume 15, pp. 30-35.

Baker, D., 2002. Differences in Strength and Power Among Junior-High, Senior-High, College-Aged and Elite Professional Rugby League Players. *Journal of Strength and Conditioning Research,* 16(4), pp. 581-585.

Baker, D. G., 2013. 10 year changes in upper body strength and power in elite rugby league players - the effects of training age, stage and content. *Journal of Strength and Conditioning Research,* Volume 27, pp. 285-292.

Baker, D. G. & Newton, R. U., 2008. Comparison of lower body strength, power, acceleration, speed, agility and sprint momentum to describe and compare playing rank among professional rugby league players. *Journal of Strength and Conditioning Research* , Volume 22, pp. 153-158.

Bangsbro, J., Iaia, F. M. & Krustrup, P., 2008. The Yo-Yo intermittant recovery test: a useful tool for evaluation of physical perfromacne in intermittent sports. *Sports Medicine,* 38(1), pp. 37-51.

Barr, M. J., Sheppard, J. M., Gabbett, T. J. & Newton, R. U., 2014. Long-term training induced changes in sprinting speed and sprint momentum in elite rugby union players. *Journal of Strength and Conditioning Research,* Volume 28, pp. 2724-2731.

Batterham, A. M. & George, K. P., 1997. Allometric modelling does not determine a dimensionless power function ratio for maximal muscular function. *Journal of Applied Physiology* , Volume 83, pp. 2158-2166.

Bell, J., Hardy, L. & Beattie, S., 2013. Enhancing mental toughness and performance under pressure in elite youn cricketers: A 2-year longitudinal intervention. *Sport, Exercise and Performance Psychology,* 2(4), p. 297.

Bell, W., 1973. Distribution of skinfolds and differences in body proportions in young adult rugby players. *Journal of Sports Medicine and Phsyical Fitness,* 13(2), pp. 69-73.

Bell, W., 1980. Body composition and maximal aerobic power of rugby union forwards. *Journla of Sports Medicine and Physical Fitness,* Volume 20, pp. 447-51.

Bull, S., Shambrook, C., James, W. & Brooks, J., 2005. Towards an understanding of mental toughness in elite english cricketers. *Journal of Applied Sports Psychology,* Volume 17, pp. 209-227.

Caldwell, B. P. & Peters, D. M., 2009. Seasonal Variation in Physiological Fitness of a Semiprofessional Soccer Team. *Journal of Strength and Conditioning Research,* 23(5), pp. 1370-1377.

Cheetham, M. E., Hazeldine, R. J. & Robinson, A., 1988. Power output of rugby forwards during maximal treadmill sprinting. In: *Science and Football*. London: E & FN Spon, pp. 206-210.

Cheng, H. L. et al., 2014. Anthropometric characteristics pf Australian junior representative rugby league players. *Journal of Science and Medicine in Sport,* Volume 17, pp. 546-551.

Clough, P. J., Earle, K. & Sewell, D., 2002. Mental toughness: The concept and its measurement. In: I. Cockerill, ed. *Solutions in sport psychology*. London: Thomson, pp. 32-43.

Cohen, J., 1969. *Statistical power analysis for the behavioral sciences.* New York: Academic Press.

Colbert, S. D., Scott, J., Dale, T. & Brennan, P. A., 2012. Performing to a world class standard udner pressure - can we learn lessons from Olympians?. *British Journal of Oral and Maxillofacial Surgery,* Volume 50, pp. 291-297.

Crust, L., 2007. Mental Toughness in Sport: A Review. *IJSEP,* Volume 5, pp. 270-290.

Crust, L., 2008. A review and conceptual re-examination of mental toughness: Implications for future researchers. *Personality and Individual Differences,* Volume 45, pp. 576-583.

Cunniffe, B., Proctor , W., Baker, J. S. & Davies, B., 2009. An evaluation of the physiological demands of elite rugby union using GPS tracking software. *Journal of Strength and Conditioning Research,* 23(4), pp. 1195-1203.

Cunniffe, B., Proctor, W., Baker, J. S. & Davies, B., 2009. An evaluation of the physioloigcal demands of elite rugby union using global positioning system tracking software. *Journal of Strength and Conditioning Research* , 23(4), pp. 1195-1203.

Darrall-Jones, J. D., Jones, B. & Till, K., 2015. Anthropometric and physical profiles of English academt rugby union players. *Journal of Strength and Conditioning Research,* 29(8), pp. 2086-2096.

Darrall-Jones, J. D., Jones, B. & Till, K., 2016. Anthropometric, sprint and high intensity running profiles of English academy rugby union players by position. *Journal of Strength and Conditioning Research,* 30(5), pp. 1348-1358.

Docherty, D., Wenger, H. A. & Neary, P., 1988. Time motion analysis related to the physiological demands of rugby. *Journal of Human Movement Studies,* Volume 14, pp. 269-277.

Duthie, G., Pyne, D. & Hooper, S., 2003. Applied physiology and game analysis of rugby union. *Journal of Sports Medicien,* Volume 33, pp. 973-991.

Duthie, G. et al., 2006. Anthropometry profiles of elite rugby players: quantifying changes in lean mass. *British Journal of Sports Medicine,* 40(3), pp. 202-207.

Ericsson, K. A., 1996. *The road to excellence: The acquisition of expert perfromance in the arts, sciences, sports and games.* Mahwah, NJ: Lawrence Erlbaum Associates.

Fitzsimmons, M., Dawson, B. & Ward , D., 1993. Cycling and running test of repeated sprint ability. *Australian Journal Sports Medicine,* 25(4), pp. 82-87.

Fontana, F. Y. et al., 2015. Anthropometrics of Italian Senior Male Rugby Union Players: From Elite to Second Division. *International Journal of Sports Physiology and Performance,* Volume 10, pp. 674-680.

Fukuda, Y., Woo, S. L. & Loh, J. C., 2003. A quantitative analysis of valgus torque on the ACL: a human cadaveric study. *Journal of Orthopaedic Research,* Volume 21, pp. 1107-1112.

Fuller, C. W., Brooks, J. H., Cancea, R. J. & Kemp, S. P., 2007. Contact events in rugby union and their propensity to casue injury. *British Journal of Sports Medicine,* Volume 31, pp. 795-802.

Fuller, C. W., Taylor, A. E., Brooks, J. H. & Kemp, S. P., 2013. Changes in the stature, body mass and age of English professional rugby players: A 10-year review. *Journal of Sports Sciences,* Volume 36, pp. 795-802.

Gabbett , T., 2006. Performance changes following a field conditioning program in junior and senior rugby league players. *Journal of Strength and Conditioning Research,* Volume 20, pp. 215-221.

Gabbett, T., 2009. Physiological and anthropometric characteristics of starters and non-starters in junior rugby league players. *Journal of Sports Medicine and Physical Fitness,* Volume 49, pp. 233-239.

Gabbett, T., 2012. Activity cycle of National Rugby League and National Youth Competition matches. *Journal of Strength and Conditioning Research,* Volume 26, pp. 1517-1523.

Gabbett, T. J., 2000. Physiological and anthropometric characteristics of amateur rugby league players. *British Journal of Sports Medicine,* Volume 34, pp. 303-307.

Gabbett, T. J., 2002. Physiological charactersitics of junior and senior rugby league players. *British Journal of Sports Medicine,* Volume 36, pp. 334-339.

Gabbett, T. J., 2005. A comparison of physiological and anthropometric characterstics among playing positions in junior rugby league players. *British Journal of Sports Medicine,* Volume 39, pp. 675-680.

Gabbett, T. J., 2005. Changes in physiological and anthropometric characteristics of rugby league players during a competitive season. *Journal of Strength and Conditioning Research,* 19(2), pp. 400-408.

Gabbett, T. J., 2005. Physiological and anthropometric characteristics of junior rugby league players over a competitive season. *Journal of Strength and Conditioning Research,* Volume 19, pp. 764-771.

Gabbett, T. J., 2006. A comparison of physiological and anthropometric characteristics among playing positions in sub-elite rugby league players. *Journal of Sports Sciences,* 24(12), pp. 1273-1280.

Gabbett, T. J., King, T. & Jenkins, D., 2008. Applied Physiology of Rugby League. *Sports Medicine,* Volume 38, pp. 119-138.

Gabbett, T., Kelly, J. & Pezet, T., 2008. A comparison of fitness and skill among playing position in sub-elite rugby league players. *Journal of Science and Medicine in Sport,* 11(6), pp. 585-592.

Gamble, P., 2004. Physical preparation for elite-level rugby union football. *Strength and Conditioning Journal,* Volume 26, pp. 10-23.

Garraway, W. M., 2000. Impact of profressionalism on injuries in rugby union. *British Journal of Sports Medicine* , Volume 34, pp. 348-351.

Gottesman, I. & Hanson, D., 2005. Human Development: Biological and Genetic Processes. *Annual review of Psychology,* Volume 56, pp. 263-286.

Gucciardi, D. F., Gordon, S. & Dimmock, J. A., 2009. Evaluation of a mental toughness training program for youth-aged Australian footballers: I. A quantitative analysis. *Journal of Applied Sports Psychology,* Volume 21, pp. 307-323.

Gucciardi, D. F., Jackson, B., Hanton, S. & Reid, M., 2015. Motivational correlates of mentally tough behabiour in tennis. *Journal of Sports and Medicine in Sport,* 18(1), pp. 67-71.

Gucciardi, D. F. et al., 2015. Implicit theories of mental toughness: Relations with cognitive, motivational and behavioural correlates.. *Sport, Exercise and Performance Psychology,* 4(2), pp. 100-112.

Gucciardi, D. F. & Jones, M. I., 2012. Beyond optimal performance: Mental toughenss profiles and development success in adolescent cricketers. *Journal of Sport and Exercise Psychology,* Volume 34, pp. 16-36.

Gucciardi, D., Gordon, S. & Dimmocj, J., 2008. Towards an understanding of metnal toughness in Australian football. *Journal of Applied Sport Psychology ,* Volume 20, pp. 261-281.

Hardy, L., Bell, J. & Beattie, S., 2014. A neuropsychological model of mentally tough behaviour. *Journal of Personality,* Volume 82, pp. 69-81.

Harmison, R. J., 2011. A social-cognitive framework for understanding and developing mental toughness in sport. In: D. F. Gucciardi & S. Gordon, eds. *Mental Toughness in Sport: Developments in reasearch and theory.* Abingdon, Oxon: Routledge, pp. 47-68.

Hazeldine , R. & McNab, T., 1991. *Fit for Rugby.* London: Kingswood Press.

Herrington, L., Myer, G. D. & Munro, A., 2013. Intra and inter-tester reliability of the tuck jump assessment. *Physical Therapy in Sport,* Volume 14, pp. 152-155.

Herrington, L., Myer, G. & Munro, A., 2013. Intra and Inter Tester Reliability of Tuck Jump Assessment. *Physical Therapy in Sport,* 14(3), pp. 152-155.

Hewett, T. E., Myer, G. D. & Ford, K. R., 2005. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *American Journal of Sports Medicine,* Volume 33, pp. 492-501.

Holmyard, D. J. & Hazeldine, R. J., 1993. Seasonal variations in the anthropometric and physioloigcal characteristics of international rugby union players. In: T. Reilly,

J. P. Clarys & A. Stibbe, eds. *Science and Football II*. Eindhoven: E and FN Spon, pp. 21-6.

Jacobson, B. H., Thompson, B. J., Conchola, E. C. & Glass, R., 2013. A comparison of absolute, ratio and allometric scaling methods for normalising strength in elite american football players. *Journal of Athletic Enhancement* , Volume 2, p. 2.

Jardine, M. A., Wiggins, T. M. & Myburgh, K. H., 1988. Physiological characteristics of rugby players including muscle glycogen content and muscle fibre composition. *South African Medical Journal* , Volume 73, pp. 529-532.

Jones, G., Hanton, S. & Connaughton, D., 2002. What is this thing called mental toughenss? An investigation of elite sport performers. *Journal of Applied Sport Psychology,* Volume 14, pp. 205-218.

Jones, G., Hanton, S. & Connaughton, D., 2007. A framework of mental toughness in the world's best performers. *The Sport Psychologist,* Volume 21, pp. 243-264.

Jones, G. & Moorhouse, A., 2007. *Developing mental toughness: Gold medal strategies for transforming your business performance*. Begbroke, Oxford: Spring Hill.

Kirkpatrick, J. & Comfort, P., 2013. Strength, Power and Speed Qualities in English Junior Elite Rugby League Players. *Journal of Strength and Conditioning Research,* 27(9), pp. 2414-2419.

Kobal, R. et al., 2016. Physical perfromance of Brazilian rugby players from different age catergoris and competitive levels. *Journal of Strength and Conditioning Research,* 30(9), pp. 2433-2439.

La Monica, M. B. et al., 2016. Physical differences between forwards and backs in American collegiate rugby players. *Journal of Strength and Conditioning Research,* 30(9), pp. 2382-2391.

Lacome, M., Piscione, J., Hager, J.-P. & Bourdin, M., 2014. A new approach to quantifying physical demand in rugby union. *Journal of Sports Sciences,* Volume 32, pp. 290-300.

Lander, J. & Webb, P., 1983. A year round strength training program for rugby. *National Strength and Conditioning Association Journal,* 5(3), pp. 32-34.

Lee, A. J., Myers, J. L. & Garraway, W. M., 1997. Influence of player's physique on rugby football injuries. *British Journal of Sports Medicine,* Volume 31, pp. 135-139.

Lloyd, D. G. & Buchanan, T. S., 2001. Strategies of muscular support of varus and valgus isometric loads at the human knee. *Journal of Biomechanics,* Volume 34, pp. 1257-1267.

Lombard, W. P. et al., 2015. Changes in Body Size and Physcial Characetristics of South African Under-20 Rugby Union Players Over a 13-Year Period. *Journal of Strength and Conditioning Research,* 29(4), pp. 980-988.

Mahoney, J. W., Gucciardi, D. F., Ntoumanis, N. & Mallet, C. J., 2014. Mental toughness in sport: Motivational antecedents and associations with performance and psychological health. *Journal of Sport and Exercise Psychology,* Volume 36, pp. 281-292.

Malina, R. M., Bouchard, C. & Bar-Or, O., 2004. *Growth, Maturation and Physical Activity.* Champaign: Human Kinetics.

Mandelbaum, B. R. et al., 2005. Effectiveness of a Neuromuscular and Proprioceptive Trainign Program in Preventing Anterior Cruciate Ligament Injuries in Female Athletes. *The American Journal of Sports Medicine,* 33(7), pp. 1003-1010.

Markolf, K. L. et al., 1995. Combined knee loading states that generate high anterior cruciate ligament forces. *Journal of Orthopaedic Research,* Volume 13, pp. 930-935.

Masten, A. S., 2011. Resilience in children threatened by extreme adversity: Franeworks for research, practice and translatational synergy. *Development and Psychopathology,* Volume 23, pp. 493-506.

Maud, P. J., 1983. Physiological and anthropometric paramters that describe a rugby union team. *British Journal of Sports Medicine,* 17(1), pp. 16-23.

Maud, P. J. & Shultz, B. B., 1984. The US national rugby team: a physiological and anthropometric assessment. *Physiology Sports Medicine,* 12(9), pp. 86-99.

Mayes, R. & Nuttall, F. E., 1995. A comparison of the physiological characteristics of senior and under 21 elite rugby union players [abstract]. *Journal of Sports Science ,* Volume 13, pp. 13-14.

McLean, D. A., 1993. Field testing in rugby union football. In: *Intermittent high intensity exercise: preparations, stresses and damage limitation.* London: E & FN Spon, p. 79.84.

Meir, R. et al., 2001. Physical fitness qualities of professional rugby league football players: Determination of positional differences. *Journal of Strength and Conditioning Research,* Volume 15, pp. 450-458.

Mercer, T., Gleeson, N. & Mitchell, J., 1997. Fitness profile of professional soccer players before and after pre-season conditioning. In: T. Reilly, J. Bangsbo & M. Hughes, eds. *Science and Football 3.* London: E and FN Spon, pp. 112-117.

Miller, L., 2008. Stress and resilience in law enforcement training and practice. *International Journal of Emergency Mental Health* , Volume 10, pp. 109-124.

Moher, D. et al., 2009. Preferred Reporting Items for Systematic Reviews Analyses: The PRISMA Statemtn. *PLoS Medicine,* 6(7), pp. 1-6.

Morehen, J. C. et al., 2015. Position specific differences in the anthropometric characteristics of elite European Super League rugby players. *European Journal of Sports Science,* 15(6), pp. 523-529.

Myer, G. D., Ford, K. R. & Hewett, T. E., 2004. Rationale and clinical techniques for anterior cruciate ligament injury prevention among female athletes. *Journal of Athletic Training,* Volume 39, pp. 352-364.

Myer, G. D., Ford, K. R. & Hewett, T. E., 2008. Tuck Jump Assessment for Reducing Anterior Cruciate Ligament Injury Risk. *Athl Ther Today,* 13(5), pp. 39-44.

Myer, G. D. et al., 2006. Rehabilitation after anterior cruciate ligament reconstruction: Criteria-based preogression through the return-to-sport phase. *Journal of Orthopaedic & Sports Physical Therapy,* 36(6), pp. 385-402.

Neilsen Sports, 2016. *World Rugby.* [Online]
Available at: http://www.worldrugby.org/news/204417

Nicholas, C. W., 1997. Anthropometric and Physiological Characteristics of Rugby Union Football Players. *Sports Medicine,* 23(6), pp. 375-396.

Nicholas, C. W. & Baker, J. S., 1995. Anthropometric and phsiological characteristics of first- and second-class rugby union players. *Journal of Sports Sciences,* Volume 13, p. 15.

Norton, K. & Olds, T., 2001. Morphological evolution of athletes over the twentieth century. *Sports Medicine,* Volume 31, pp. 763-783.

Ntoumanis, N., 2002. Motivational clusters in a sample of British physical education classes. *Psychology of Sport & Exercise,* Volume 3, pp. 177-194.

Olds, T., 2001. The evolution of physique in male rugby union players in the twentieth century. *Journal of Sports Sciences,* 19(4), pp. 253-262.

Olds, T., 2001. The evolution of physique in male rugby union players in the twentieth century. *Journal of Sports Science,* Volume 19, pp. 253-262.

Patel, D. R., 2010. Sport-related perfroamcen anxiety in young female athletes. *Journal of Pediatric and Adolescent Gynecology,* Volume 23, pp. 325-335.

Peterson, M. D., Alvar, B. A. & Rhea, M. R., 2006. The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of Strength and Conditioning Research* , Volume 20, pp. 867-873.

Quarrie , K. L. & Wilson, B. D., 2000. Force production in the rugby union scrum. *Journal of Sports Science,* Volume 19, pp. 237-246.

Quarrie, K. L., Handcock, P., Toomey, M. J. & Waller, A. E., 1996. The New Zealand rugby injury and performance project. IV. Anthropometric and physical performance comparisons between positional categories of senior A rugby players. *British Journal of Sports Medicine,* Volume 30, pp. 53-56.

Quarrie, K. L. et al., 1995. The New Zealand rugby injury and performance project. III. Anthropometric and physical performance characteristics of players. *British Journal of Sports Medicine,* 29(4), pp. 263-270.

Quarrie, K. L. & Hopkins, W. G., 2007. Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004. *Journal of Sports Science,* Volume 25, pp. 895-903.

Reid, R. M. & Williams, R., 1974. A concept of fitness and its measurement in relation to rugby football. *British Journal of Sports Medicine,* Volume 8, pp. 96-99.

Rigg, P. & Reilly , T., 1988. *A fitness profile and anthropometric analyiss of first and second class rugby union players*. London: E. & F. N. Spon.

Roberts, S. P. et al., 2008. The physical demands of elite English rugby union. *Journal of Sports Science,* Volume 26, pp. 825-833.

Robinson, P. D. & Mills, S. H., 2000. Relationship between scrummaging strength and standard field test for power in rugby. In: *Proceedings of XVIII International Symposiun on Biomechanics of Sports*. Hong Kong: Y. Hong , pp. 980-981.

Schaefer, J., Vella, S. A., Allen, M. S. & Magee, C. A., 2016. Competition anxiety, motivation and mental toughness in golf. *Journal of Applied Sports Psychology,* 28(3), pp. 309-320.

Sedeaud, A., 2012. How they won Rugby World Cup through height, mass and collective experience. *British Journal of Sports Medicine* , Volume 46, pp. 580-584.

Sheard, M., 2010. *Mental Toughness: The mindset behind sporting achievement*. East Sussex: Routledge.

Sheard, M. & Golby, J., 2006. Effect of psychological skills training program on swimming performance and positive psychologicl development. *International Journal of Sport and Exercise Psychology* , Volume 2, pp. 7-24.

Sheard, M., Golby, J. & Van Wersch, A., 2009. Progress towards construct validation of the Sports Mental Toughness Questionnaire (SMTQ). *European Journal of Psychological Assessment,* Volume 25, pp. 186-193.

Smart, D., Hopkins, W. G., Quarrie, K. L. & Gill, N., 2014. The relationship between physical fitness and game behaviours in rugby union players. *European Journal of Sports Sciences,* 14(Suppl 1), pp. S8-S17.

Smart, D. J., Hopkins, W. G. & Gill, N. D., 2013. Differences and changes in the physcial characteristics of professional and amateur rugby union players. *Journal of Strength and Conditioning Research,* 27(11), pp. 3033-3044.

Smith, I., 2012. *The Roar.* [Online]
Available at: http://www.theroar.com.au/2012/09/03/how-long-is-a-rugby-match-really/

Sporis, G., Ruzic, L. & Leko, G., 2008. The anaerobic endurance of elite soccer players improved after a high-intensity trainign intervention in the 8-week conditioning program. *The Journal of Strength and Conditioning Research,* 22(2), pp. 559-566.

Spreitzer, G. et al., 2005. A socially embedded model of thriving at work. *Organisation Science,* Volume 16, pp. 537-549.

Sulliven, G. M., 2012. Using Effect Size - or Why the P Value Is Not Enough. *Journal of Graduate Medicine,* 4(3), pp. 279-282.

Tarnopolsky, M. A., 2008. Building muscle: Nutrition to maximise bulk and strength adaptations to resistance exercise training. *European Journal of Sports Science,* Volume 8, pp. 67-76.

Till, K. et al., 2013. A longitudinal evaluation of anthropometric and fitness characteristics in junior rugby league players considering playing position and selection level. *Journal of Science and Medicine in Sport ,* Volume 16, pp. 438-443.

Till, K. et al., 2015. Longitudinal development of anthropometric and physical characteristics within academy rugby league players. *Journal of Strength and Conditioning Research,* 29(6), pp. 1713-1722.

Till, K. et al., 2014. Seasonal changes in anthropometric and physical characetristics within English academy rugby league players. *Journal of Strength and Conditioning,* Volume 28, pp. 2689-2696.

Till, K. et al., 2014. Anthropometric and physical characteristics of English academy rugby league players. *Journal of Strength and Conditioning Research ,* Volume 28, pp. 319-327.

Tong, R. J. & Mayes, R., 1995. The effect of pre-season training on the physiological characteristics of international rugby union players. *Journal of Sports Sciences,* Volume 13, p. 507.

Ueno, T., Watai, E. & Ishii, K., 1988. Aerobic and anaerobic power of rugby football players. In: T. Reilly, A. Lees & K. David, eds. *Science and Football.* London: E and FN Spon, pp. 201-5.

Vallerand, R. J. & Losier, G. F., 1999. An integrative analysis of intrinsic and extrinsic motivation in sport. *Journal of Applied Sport Psychology,* Volume 11, pp. 142-169.

van Rooyen, M., Rock, K., Prim, S. & Lambert, M., 2008. The quantification of contacts with impact during professional rugby matches. *International Journal of Performance Analysis in Sport,* Volume 8, pp. 113-126.

Waldron, M., Worsefold, P., Twist, C. & Lamb, K., 2014. Changes inanthropometry and performance, and their interrelationships, across three seasons in elite youth rugby league players. *Journal of Strength and Conditioning Research,* 28(11), pp. 3128-3136.

Warrington, G., Ryan, C. & Murray, F., 2001. Physiological and metabolic characteristics of elite tug of war athlete. *British Journal of Sports Medicine,* 35(6), pp. 396-401.

Williams, C., Reid, R. M. & Coutts, R., 1973. Observations on the aerobic power of university rugby players and professional soccar players. *British Journal of Sports Medicine* , Volume 7, pp. 390-391.

World Rugby, 2009. *Laws of the Game Rugby Union.* [Online]
Available at: http://laws.worldrugby.org/?law=1&language=en

World Rugby, 2016. *World Rugby.* [Online]
Available at: file:///C:/Users/user/Downloads/2016-PARTICIPATION-MAP-FINAL.pdf

Young, W., 2005. Physiological and anthropometric chracteristics of starts and non-starts and playing position in elite Australian Rules football: a case study. *Journal of Science and Medicine in Sport,* 8(3), pp. 333-345.

# 8. APPENDIX

## 8.1 Systematic Review Tables

### 8.1.1 Search Summary

| Study Type | Articles | Participants | Age | Playing Level | Battery of Test |
|---|---|---|---|---|---|
| Rugby Union | 9 | 1079 | 14 - 31 | Amateur to Elite | Physiological and Anthropometric |
| Rugby League | 9 | 1294 | 16 - 30 | Amateur to Elite | Physiological and Anthropometric |
| Longitudinal Studies | 9 | 2019 | 13-28 | Amateur to Elite | Physiological and Anthropometric |

### 8.1.2 Rugby Union Studies: Comparison of Performance Measures

| Reference | Subjects | Level | Tests | Positional Groups | Findings |
|---|---|---|---|---|---|
| Kobal et al, 2016 | 88 | U15, U17, U19, Senior Professional and National | Anthropometry, SJ, CMJ, 2 Agility Tests (COD test and Pro-Agility), YoYo IRT-1. | Levels | Comparisons of playing level showed improvements in performance measures. |
| La Monica et al, 2016 | 25 | Collegiate | Anthropometry 1RM Strength, CMJ, Mid-Thigh Pull, Maximal Aerobic Capacity, Agility, Speed. | Backs and Forwards | Forwards gave greater body mass, BF (%), absolute strength and peak force. Back greater aerobic capacity |
| Darrell-Jones et al, 2015 | 67 | U16, U18 and U21 | Anthropometry, Speed, Agility, CMJ, YoYo IRT-1, 30-15 IFT, 3RM Strength, Isometric Mid-Thigh Pull. | Age Groups | Anthropometric and physical qualities develop across age categories. |
| Darrell-Jones et al, 2015 | 67 | U16, U18 and U21 | Anthropometry, Speed, YoYo IRT-1, 30-15 IFT, | Age Groups; Backs and Forwards | Comparative data for positional differences in anthropometric, sprint and high intensity running ability. |
| Fontana et al, 2015 | 362 | Second Division to Elite | Anthropometry | Playing Level and Forwards and Backs | Clear progressive changes in anthropometrics from the lower level to Elite |

**8.1.2 Rugby Union Studies: Comparison of Performance Measures Continued**

| Reference | Subjects | Level | Tests | Positional Groups | Findings |
|---|---|---|---|---|---|
| Quarrie et al, 1995 | 264 | U18/19, U20, Senior B and Senior A | MSFT, CMJ, Agility, Upper Body Muscular Endurance, 30m Sprint and 6 Repeated Sprint Test. | Age Groups; Backs and Forwards | Forwards greater momentum due to increased body mass but may compromise fitness and speed. |
| Quarrie et al, 1996 | 94 | Senior A | MSFT, CMJ, Agility, Upper Body Muscular Endurance, Speed, Repeated Sprint Ability. | Props, Hookers, Locks, Loose Forwards, Inside Backs, Midfield Backs and Outside Backs | Positional differences are definitely evident. |
| Wood et al, 2016 | | Elite Youth Irish Rugby Players | Anthropometry, CMJ, Triple Hop, Speed, 150m shuttle test | Forwards and Backs | Forwards were taller and heavier. Back higher CMJ and longer Triple Hop. Backs faster 10m times and higher 150m shuttle test score. |
| Argus et al, 2012 | 112 | High School to Elite | Strength and Power | Playing Level | Both strength and power can discriminate between playing levels. |

### 8.1.3 Rugby League Studies: Comparison of Physical Performance Measures

| Reference | Subjects | Level | Tests | Positional Groups | Findings |
|---|---|---|---|---|---|
| Gabbett, 2006 | 215 Forwards and 200 Backs | Sub-elite | Anthropometry, CMJ, Speed, Agility, MSFT. | Prop, Hooker, Second Row, Back Row, Scrum-Half, Stand Off, Centre Wing and Fullback | Few physiological and anthropometric differences exist between sub-elite players |
| Gabbett, 2002 | 159 | U13-U16 n = 88 (Junior) , First and Second Grade and U19 n = 71 (Senior) | Body mass, CMJ, Speed, Agility, MSFT. | Age Groups | Progressive development of physiological abilities as playing level increases |
| Cheng et al, 2013 | 116 | Junior | Anthropometry, Five Girths and Two Bone Widths. | Backs and Forwards, Ethnicity, | Greater mass evident for forwards. |
| Gabbett, 2000 | 35 | Amateur Adults | Anthropometry, CMJ, Speed, MSFT. | Backs and Forwards | The physiological and anthropometric properties of youth players are poorly developed. |
| Gabbett, 2005 | 240 | Junior Males | Anthropometry, CMJ, Speed, Agility, MSFT. | Prop, Hooker, Second Row, Back Row, Scrum-Half, Stand Off, Centre Wing and Fullback | Few physiological and anthropometric differences exist between youth Rugby League positions |

### 8.1.3 Rugby League Studies: Comparison of Physical Performance Measures Continued

| Reference | Subjects | Level | Tests | Positional Groups | Findings |
|---|---|---|---|---|---|
| Morehen et al, 2015 | 112 | Elite Males | DEXA - Height, Body mass, Lean Mass, Fat Mass, Body Fat Percentage | Props, Hookers, Back Row, Halfbacks, Centres, Wingers and Fullbacks | Low inter positions differences but large intra position differences. |
| Kirkpatrick and Comfort, 2013 | 24 | Elite Junior English Rugby League Players | Speed, CMJ, Strength and Anthropometry | Forwards and Backs | Sprint speeds were different between positions |
| Gabbett et al, 2008 | 98 | Sub-elite Rugby League players | Anthropometry, CMJ, Speed, Agility and MSFT. | Positional Split | Performance measures vary between playing position |
| Baker, 2002 | 95 | Untrained Junior High Rugby League players to Elite Players | Upper and Lower Body Strength and Power | Untrained Junior High-School, Junior High-School, Senior High-School, Collegiate and Elite NRL | Clear strength and power progression pathway from High-School to Elite level |

### 8.1.4 Longitudinal Studies: Breakdown of Performance Measures Tracked and Compared

| Reference | Subjects | Level | Tests | Comparison | Duration | Findings |
|---|---|---|---|---|---|---|
| Till et al, 2014 | 133 youth Rugby League Players | U16 - U20 | Anthropometry, CMJ, Speed, YoYo IRT-1, 1RM Squat Bench and Prone Row. | Backs and Forwards | Data collected over 6 years | Performance Measures develop across annual-age and between backs and forwards. |
| Wardron et al, 2014 | 13 Elite Youth Rugby League Players | Youth | Anthropometry, Limb Length and Circumference, Predicted Muscle CSA, Speed, CMJ, Vertical Power and Aerobic Power. | Age Group Comparison | 3 year transition of athletes from U15 to U17 | Concomitant changes between U15 and U16 for 20m Speed and predicted Vertical Power. |
| Smart et al, 2013 | 1161 New Zealand Rugby Union Players | Adult | Body Composition, Strength, Power, Speed and Repeated Sprint Ability. | Backs and Forwards and Playing Level | 2004-2007 | Performances improve with increased level of playing ability. |
| Appleby et al, 2012 | 20 | Professional Rugby Union Players | Anthropometry, Lean Mass Index, 1RM Squat and Bench (also isometric scaled) | Each Year | Two Years Applied Resistance Training: 2007-2009 | Maximal upper and lower body strength improves. |
| Lombard et al, 2015 | 453 | South African U20 Rugby Union Players | Anthropometry, Strength, Endurance and Speed. | Each Year | 13 years | Over the duration players because taller, heavier, stronger, faster and improved muscular endurance |

### 8.1.4 Longitudinal Studies: Breakdown of Performance Measures Tracked and Compared Continued

| Reference | Subjects | Level | Tests | Comparison | Duration | Findings |
|---|---|---|---|---|---|---|
| Gabbett, 2005 | 68: 52 training and 16 non-exercise (control) | Adult - No younger than 18- Rugby League | Anthropometry, CMJ, Speed (10, 20m and 40m), Agility (L run) and MSFT | Testing Time Points | One Season: Off-Season, Pre-Season, Mid-Season, End-Season | Greatest muscular power, maximal aerobic capacity and skinfold thickness at start of season. |
| Till et al, 2015 | 15 | Youth Rugby League | Anthropometry, Speed, 10m Momentum, CMJ, YoYo IRT-1, 1RM Squat, Bench and Prone Row. | Each Group | Transition over Four Years: U16 - U20 | Greater changes seen at beginning of programme with the younger athletes |
| Till et al, 2014 | 75 Rugby League Players | Under 14,16,18,20 | Anthropometry, Speed, 1RM Squat, Bench and Prone Row, YoYo IRT-1 and CMJ. | Each Year | Transition over Six Years | Greater seasonal improvements in body mass and vertical height = U14 and U16. Contract greater improvement in $\dot{V}O_2max$ and Speed seen in U18 and U20. Seasonal strength improvements greater for U18 than U20. |
| Till et al, 2013 | 81 | Junior Rugby League Players | Anthropometry, Lower and Upper Body Power, Speed, Change of Direction, Maximal Aerobic Power. | U13, U14 and U15 Players | Two Year Period | Significant improvements across annual-age categories. |

## 8.2 Study Information Sheet (Parent/Guardian and Player)

**STUDY INFORMATION DOCUMENT**

University of Glasgow | College of Medical, Veterinary & Life Sciences

**Determination and comparison of anthropometric, physiological and psychological performance measures in elite youth Rugby Union players at four different stages of professional development across three time points during a competitive season and the longitudinal changes of each age group**

**Invitation to take part:**

The University of Glasgow invites you to take part in a research study looking at various fitness measures across different playing levels in Rugby Union. Please read the following information to give you an understanding as to why the research is being done and what taking part will involve. If you have any further questions about taking part in the study please get in touch, contact details are at the bottom of the sheet.

**What is the purpose of this study?**

The purpose of this study is to find out more accurate information about the anthropometric, physiological and psychological characteristics of players in different levels of elite youth rugby and the changes in these measures across a competitive season.

**Do I have to take part?**

Taking part in the study is voluntary. If you do decide to take part you will be asked to sign a consent form. You are also free to withdraw from the study at any time, without having to give a reason and without consequence.

**What will happen to me if I take part?**

You will be asked to complete a series of fitness tests over a 14-day period. Many of these tests will be familiar to you. These include body mass measures, YoYo IRT-1, Repeated Sprint Ability (RSA) test, 30m maximal linear sprint, 3 Rep Max (3RM) in squat, bench and chin, 505 agility test and Countermovement jump. Other tests, with which you may not be familiar, include body fat estimation through BodPod, and the Tuck Jump Test. The BodPod measures how much air you displace from a small sealed chamber. You would be required to be seated, without moving, in this small sealed chamber, with a window for approximately 1 minute. It is completely pain free and completely non-invasive. These tests will be repeated once at the beginning, once during and finally at the end of the season.

**What are the possible disadvantages and risks of taking part?**

We believe there are no disadvantages in participating in this study. However both laboratory and field based testing requires maximal effort so can produce transient periods of feeling exhausted. There is very little risk involved in taking part in this study beyond the normal relatively short-lived feelings of exertion you experience when you completed most of these tests before.

**What are the possible benefits of taking part?**

A benefit of taking part in the study is that data from your tests will be used to help us understand the different fitness levels seen at different levels of rugby development and clarify the differential between Academy level players and the effects of a season on these measures. The results from your tests will be available for you and may help give you an insight into many aspects of your own fitness levels; areas of strengths and areas for improvement.

**Will my taking part in this study be kept confidential?**

Other players involved in the study will be aware you are involved because you will see each other at testing days. Your coaches will also be aware that you are involved in the study because they will know who is going to the testing sessions. At the start of the study, you will be assigned an ID code and thus any data collected about you will be recorded and stored using your unique ID code. This code will only be known to the immediate research group. Individuals will not be identified when the study is written up. Complete confidentiality of participants will be maintained during presentation or written work related to the study.

**What will happen to the results of the research study?**

The summarized findings will be written up for submission to the University of Glasgow towards Jack's Masters by Research. They will also be written up as an article to submit to a scientific journal in the hope the findings will be published. The results will also be presented to the Director of the SRU Academy (West). You can also receive the results in the form of a summary report if you wish to see the findings for yourself. The raw data will only be accessed by the research team and BT Academy Coaches (Mr. Iain Monaghan, Mr. Graham Shiels, Miss Kat Gallagher and Mr. Derrick Speirs) and Director of SRU Academy West (Mr. Jamie Dempsey) and not be used in squad or team selection processes. The results may be used by coaches to help inform training or recovery procedures for you, the Whole Squad or for future players.

**Who is organizing and funding the research?**

The research will be carried out by Jack Urquhart, a Masters student in Physiology & Sports Science. The project will be supervised by Victoria Penpraze, University Teacher. The project is not funded by an organisation or company.

**Who has reviewed the study?**

This study has been reviewed and approved by the Research Ethics Committee of the College of Medical, Veterinary and Life Sciences at Glasgow University. Contact for Further Information:

Victoria Penpraze Tel. 07900 811734 E-mail: Victoria.Penpraze@glasgow.ac.uk

Jack Urquhart Tel: 07795 976166 E-mail: j.urquhart1@research.gla.ac.uk

Thank you for taking your time to read this information. Please keep this copy of the information sheet and a signed consent form to keep should you wish to take part.

Who has reviewed the study? This study has been reviewed and approved by the Research Ethics Committee of the College of Medical, Veterinary and Life Sciences at Glasgow University.

Thank you for taking your time to read this information.

Please keep this copy of the information sheet and a signed consent form to keep should you wish to take part.

## 8.3 Lab Based Protocol for Anthropometric Measure

Height was measured using a Leicester height stand where heels together and at the back of the board and contacts from buttocks and upper back to the pole. Height was positioned so the eyes lay in line with the middle of the ear (ISAK standard) and a large breathe in was completed. The unit was slid down onto the participants head and a measure was taken. This protocol was repeated every time they came into the lab over the season to account for any growth.

BodPod - Change into swimming trunks and don a swim cap, then be seated in the BodPod chamber with hands placed on their thighs and asked to remain still during the measurement.

The measurement was repeated at least twice, possibly a third time, to ensure consistency (within 5%) and body composition estimation completed using proprietary software.

## 8.4 Tuck Jump Assessment Scoring Sheet

# Tuck Jump Test

**Date:** **Name:**

**Condition:** **Left Right Bilateral**

| | Score |
|---|---|
| **Knee and thigh motion** | |
| 1. Knee valgus on landing | |
| 2. Thighs not reaching parallel (peak of jump) | |
| 3. Thighs not equal side to side (during flight) | |
| **Foot position during landing** | |
| 4. Foot placement not shoulder width apart | |
| 5. Foot placement not parallel (front to back) | |
| 6. Foot contact timing not equal | |
| 7. Does not land in same foot print | |
| 8. Excessive landing contact noise | |
| **Plyometric technique** | |
| 9. Pause between jumps | |
| 10. Technique declines prior to 10 seconds | |
| **Total Score** | |

# 8.5 YoYo Intermittent Recovery Test-1 Score Sheet

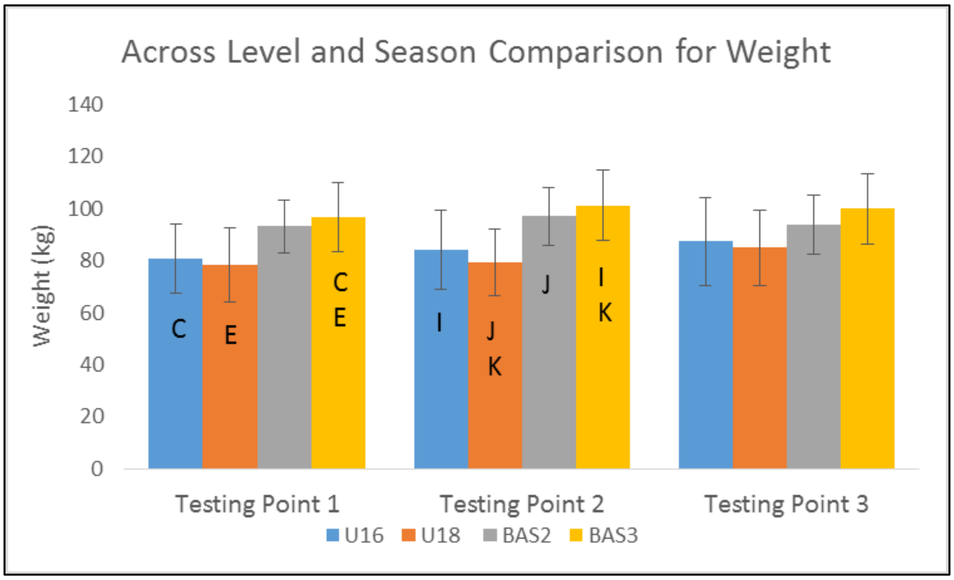
| Yo-Yo Intermittent Recovery Test - Level 1 | | | | | | |
|---|---|---|---|---|---|---|
| Speed Level | Shuttle No. | speed (km/hr) | level time (s) | accumulated shuttle dist (m) | Cumulative Time* (s) | Approx Vo2max (mL/min/kg) |
| 5 | 1 | 10 | 14.4 | 40 | 00:24 | 36.74 |
| 9 | 1 | 12 | 12.5 | 80 | 00:46 | 37.07 |
| 11 | 1 | 13 | 11.1 | 120 | 01:07 | 37.41 |
| 11 | 2 | 13 | 11.1 | 160 | 01:29 | 37.74 |
| 12 | 1 | 13.5 | 10.7 | 200 | 01:49 | 38.08 |
| 12 | 2 | 13.5 | 10.7 | 240 | 02:10 | 38.42 |
| 12 | 3 | 13.5 | 10.7 | 280 | 02:31 | 38.75 |
| 13 | 1 | 14 | 10.3 | 320 | 02:51 | 39.09 |
| 13 | 2 | 14 | 10.3 | 360 | 03:11 | 39.42 |
| 13 | 3 | 14 | 10.3 | 400 | 03:31 | 39.76 |
| 13 | 4 | 14 | 10.3 | 440 | 03:52 | 40.10 |
| 14 | 1 | 14.5 | 9.9 | 480 | 04:12 | 40.43 |
| 14 | 2 | 14.5 | 9.9 | 520 | 04:32 | 40.77 |
| 14 | 3 | 14.5 | 9.9 | 560 | 04:51 | 41.10 |
| 14 | 4 | 14.5 | 9.9 | 600 | 05:11 | 41.44 |
| 14 | 5 | 14.5 | 9.9 | 640 | 05:31 | 41.78 |
| 14 | 6 | 14.5 | 9.9 | 680 | 05:51 | 42.11 |
| 14 | 7 | 14.5 | 9.9 | 720 | 06:11 | 42.45 |
| 14 | 8 | 14.5 | 9.9 | 760 | 06:31 | 42.78 |
| 15 | 1 | 15 | 9.6 | 800 | 06:51 | 43.12 |
| 15 | 2 | 15 | 9.6 | 840 | 07:10 | 43.46 |
| 15 | 3 | 15 | 9.6 | 880 | 07:30 | 43.79 |
| 15 | 4 | 15 | 9.6 | 920 | 07:50 | 44.13 |
| 15 | 5 | 15 | 9.6 | 960 | 08:09 | 44.46 |
| 15 | 6 | 15 | 9.6 | 1000 | 08:29 | 44.80 |
| 15 | 7 | 15 | 9.6 | 1040 | 08:48 | 45.14 |
| 15 | 8 | 15 | 9.6 | 1080 | 09:08 | 45.47 |
| 16 | 1 | 15.5 | 9.3 | 1120 | 09:27 | 45.81 |
| 16 | 2 | 15.5 | 9.3 | 1160 | 09:47 | 46.14 |
| 16 | 3 | 15.5 | 9.3 | 1200 | 10:06 | 46.48 |
| 16 | 4 | 15.5 | 9.3 | 1240 | 10:25 | 46.82 |
| 16 | 5 | 15.5 | 9.3 | 1280 | 10:44 | 47.15 |
| 16 | 6 | 15.5 | 9.3 | 1320 | 11:04 | 47.49 |
| 16 | 7 | 15.5 | 9.3 | 1360 | 11:23 | 47.82 |
| 16 | 8 | 15.5 | 9.3 | 1400 | 11:42 | 48.16 |
| 17 | 1 | 16 | 9 | 1440 | 12:01 | 48.50 |
| 17 | 2 | 16 | 9 | 1480 | 12:20 | 48.83 |
| 17 | 3 | 16 | 9 | 1520 | 12:39 | 49.17 |
| 17 | 4 | 16 | 9 | 1560 | 12:58 | 49.50 |
| 17 | 5 | 16 | 9 | 1600 | 13:17 | 49.84 |
| 17 | 6 | 16 | 9 | 1640 | 13:36 | 50.18 |
| 17 | 7 | 16 | 9 | 1680 | 13:55 | 50.51 |
| 17 | 8 | 16 | 9 | 1720 | 14:14 | 50.85 |
| 18 | 1 | 16.5 | 8.7 | 1760 | 14:33 | 51.18 |
| 18 | 2 | 16.5 | 8.7 | 1800 | 14:52 | 51.52 |
| 18 | 3 | 16.5 | 8.7 | 1840 | 15:10 | 51.86 |
| 18 | 4 | 16.5 | 8.7 | 1880 | 15:29 | 52.19 |
| 18 | 5 | 16.5 | 8.7 | 1920 | 15:48 | 52.53 |
| 18 | 6 | 16.5 | 8.7 | 1960 | 16:07 | 52.86 |
| 18 | 7 | 16.5 | 8.7 | 2000 | 16:25 | 53.20 |
| 18 | 8 | 16.5 | 8.7 | 2040 | 16:44 | 53.54 |
| 19 | 1 | 17 | 8.5 | 2080 | 17:03 | 53.87 |
| 19 | 2 | 17 | 8.5 | 2120 | 17:21 | 54.21 |
| 19 | 3 | 17 | 8.5 | 2160 | 17:39 | 54.54 |
| 19 | 4 | 17 | 8.5 | 2200 | 17:58 | 54.88 |
| 19 | 5 | 17 | 8.5 | 2240 | 18:16 | 55.22 |
| 19 | 6 | 17 | 8.5 | 2280 | 18:35 | 55.55 |
| 19 | 7 | 17 | 8.5 | 2320 | 18:53 | 55.89 |
| 19 | 8 | 17 | 8.5 | 2360 | 19:12 | 56.22 |
| 20 | 1 | 17.5 | 8.2 | 2400 | 19:30 | 56.56 |
| 20 | 2 | 17.5 | 8.2 | 2440 | 19:48 | 56.90 |
| 20 | 3 | 17.5 | 8.2 | 2480 | 20:07 | 57.23 |
| 20 | 4 | 17.5 | 8.2 | 2520 | 20:25 | 57.57 |
| 20 | 5 | 17.5 | 8.2 | 2560 | 20:43 | 57.90 |
| 20 | 6 | 17.5 | 8.2 | 2600 | 21:01 | 58.24 |
| 20 | 7 | 17.5 | 8.2 | 2640 | 21:19 | 58.58 |
| 20 | 8 | 17.5 | 8.2 | 2680 | 21:38 | 58.91 |
| 21 | 1 | 18 | 8.0 | 2720 | 21:56 | 59.25 |
| 21 | 2 | 18 | 8.0 | 2760 | 22:14 | 59.58 |
| 21 | 3 | 18 | 8.0 | 2800 | 22:32 | 59.92 |
| 21 | 4 | 18 | 8.0 | 2840 | 22:50 | 60.26 |
| 21 | 5 | 18 | 8.0 | 2880 | 23:08 | 60.59 |
| 21 | 6 | 18 | 8.0 | 2920 | 23:26 | 60.93 |
| 21 | 7 | 18 | 8.0 | 2960 | 23:44 | 61.26 |
| 21 | 8 | 18 | 8.0 | 3000 | 24:02 | 61.60 |
| 22 | 1 | 18.5 | 7.8 | 3040 | 24:19 | 61.94 |
| 22 | 2 | 18.5 | 7.8 | 3080 | 24:37 | 62.27 |
| 22 | 3 | 18.5 | 7.8 | 3120 | 24:55 | 62.61 |
| 22 | 4 | 18.5 | 7.8 | 3160 | 25:13 | 62.94 |
| 22 | 5 | 18.5 | 7.8 | 3200 | 25:31 | 63.28 |
| 22 | 6 | 18.5 | 7.8 | 3240 | 25:48 | 63.62 |
| 22 | 7 | 18.5 | 7.8 | 3280 | 26:06 | 63.95 |
| 22 | 8 | 18.5 | 7.8 | 3320 | 26:24 | 64.29 |
| 23 | 1 | 19 | 7.6 | 3360 | 26:42 | 64.62 |
| 23 | 2 | 19 | 7.6 | 3400 | 26:59 | 64.96 |
| 23 | 3 | 19 | 7.6 | 3440 | 27:17 | 65.30 |
| 23 | 4 | 19 | 7.6 | 3480 | 27:34 | 65.63 |
| 23 | 5 | 19 | 7.6 | 3520 | 27:52 | 65.97 |
| 23 | 6 | 19 | 7.6 | 3560 | 28:09 | 66.30 |
| 23 | 7 | 19 | 7.6 | 3600 | 28:27 | 66.64 |
| 23 | 8 | 19 | 7.6 | 3640 | 28:45 | 66.98 |

* Cumulative time includes 10 second recovery period between shuttles

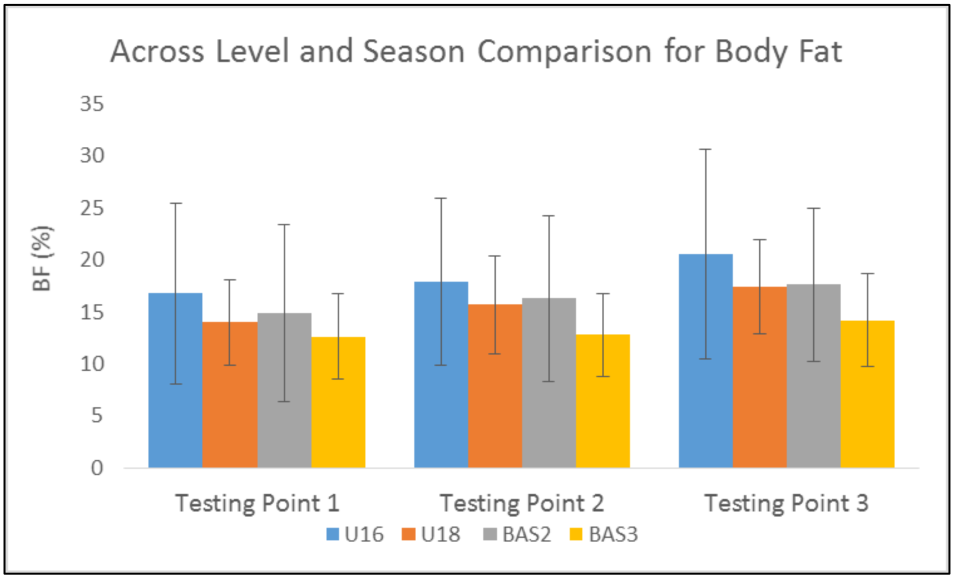
## 8.6 Whole Squad Comparison Graphs

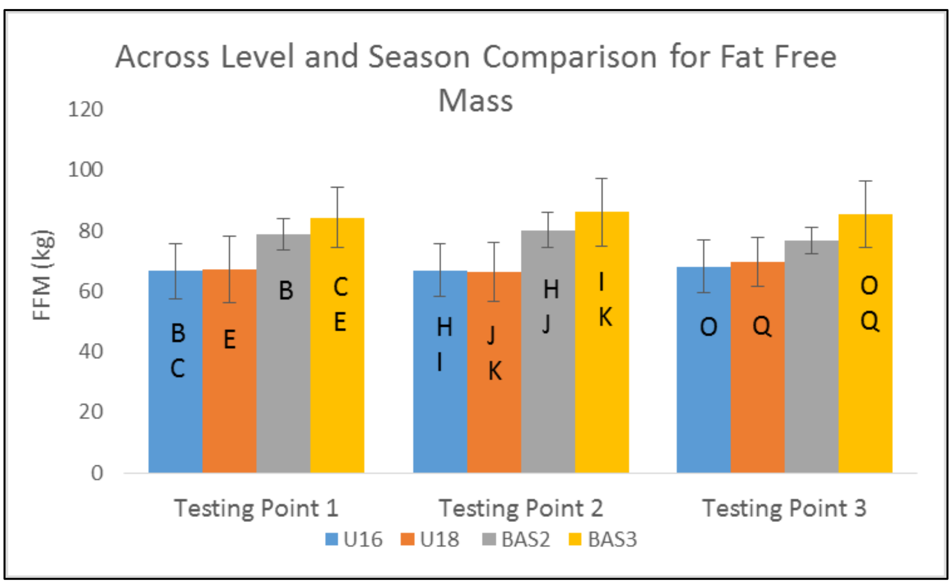
### 8.6.1 Whole Squad Cross Level and Seasonal Anthropometric Testing Data Comparison Graphs

All graphs are annotated to illustrate significant differences. If bars contain the same letter then they are significant different from one another. The symbols above the bars identify significant differences between for cross season analysis. Similarly, if two bars have the same symbol then they are significantly different.

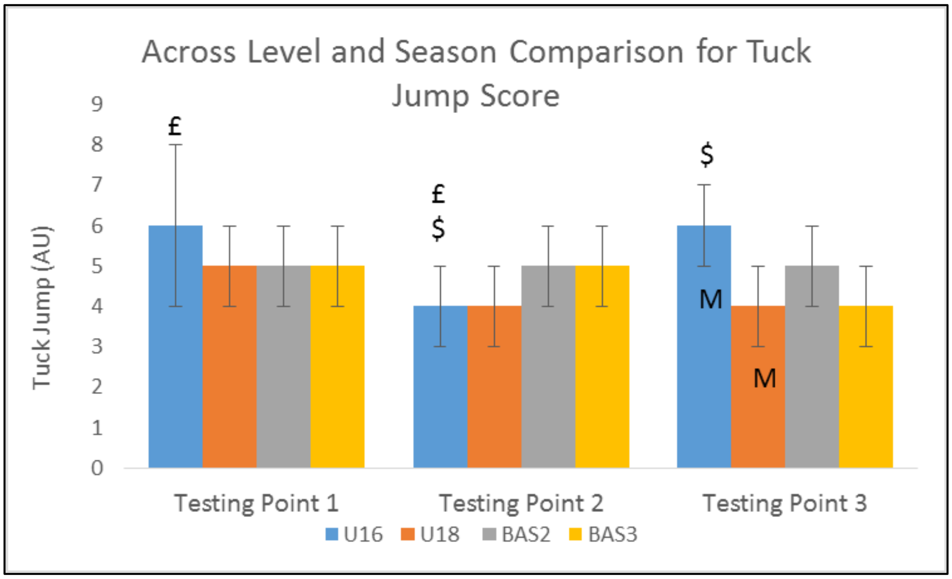


## 8.6.1 Whole Squad Cross Level and Seasonal Anthropometric Testing Data Comparison Graphs Continued

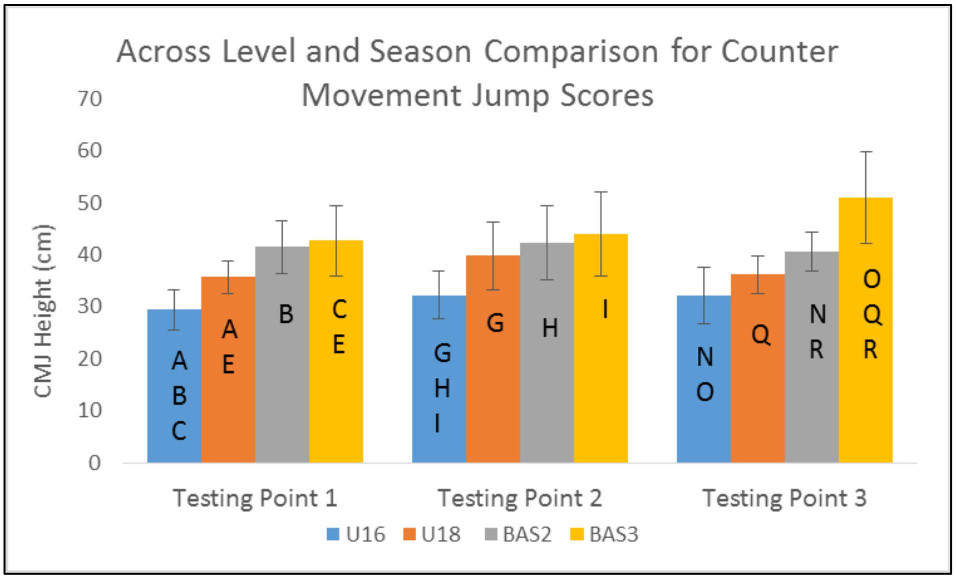


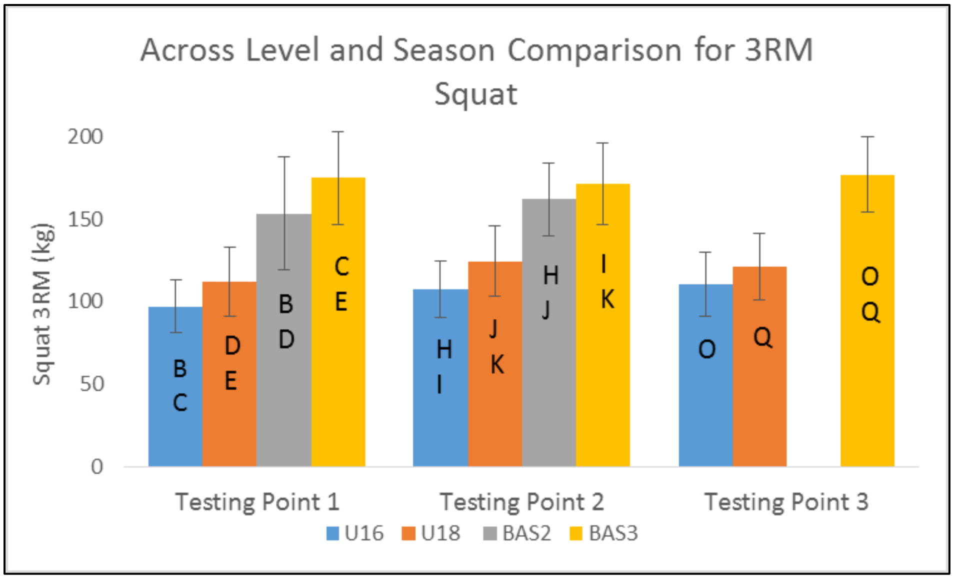
### 8.6.2 Whole Squad Cross Level and Seasonal Functional Movement Data Comparison Graph

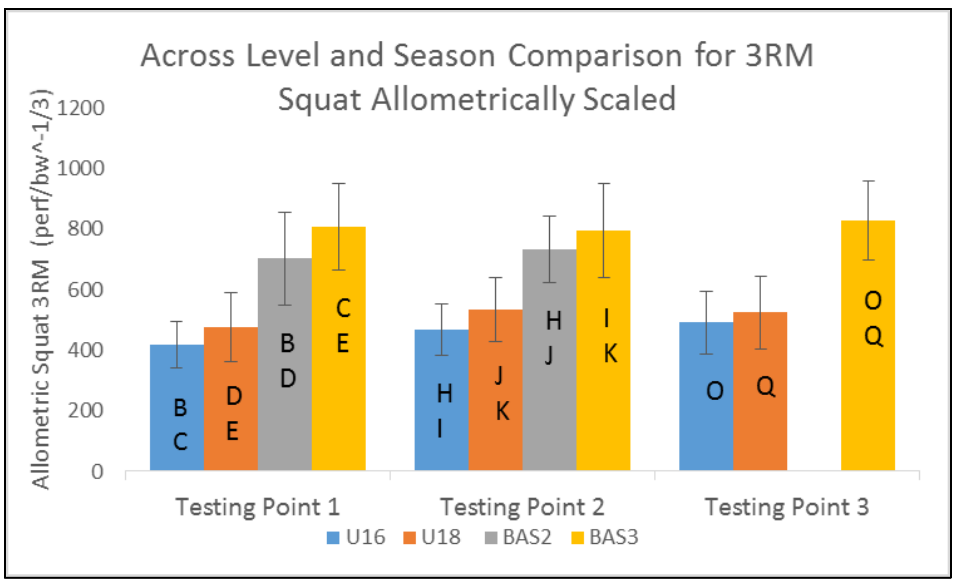


### 8.6.3 Whole Squad Cross Level and Seasonal Lower Body Power Testing Data Comparison Graphs

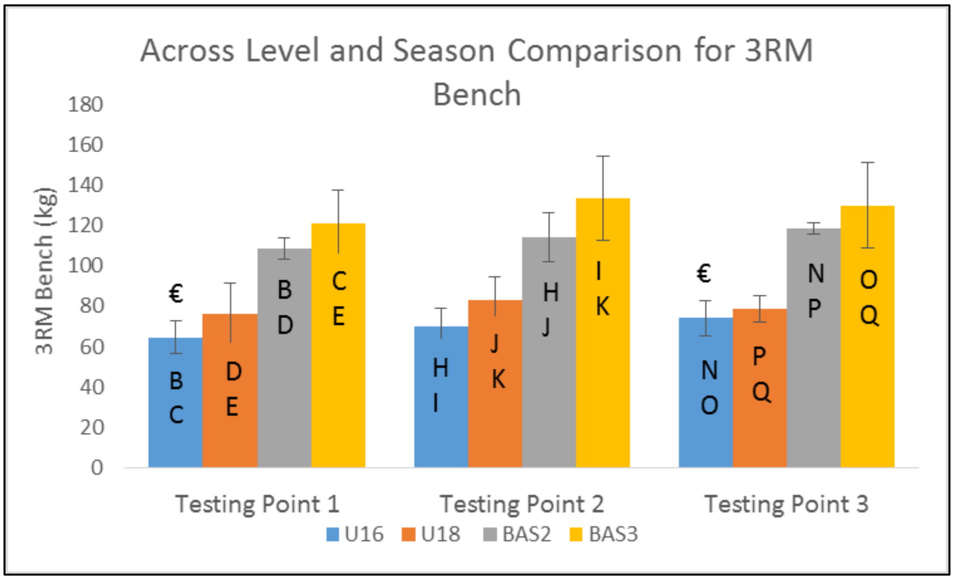


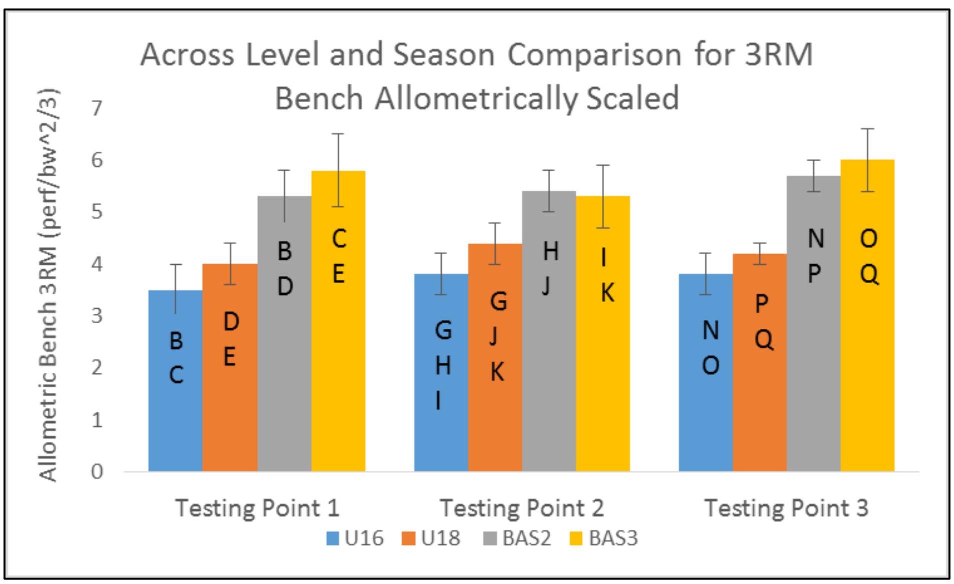
### 8.6.4 Whole Squad Cross Level and Seasonal Strength Testing Data Comparison Graphs



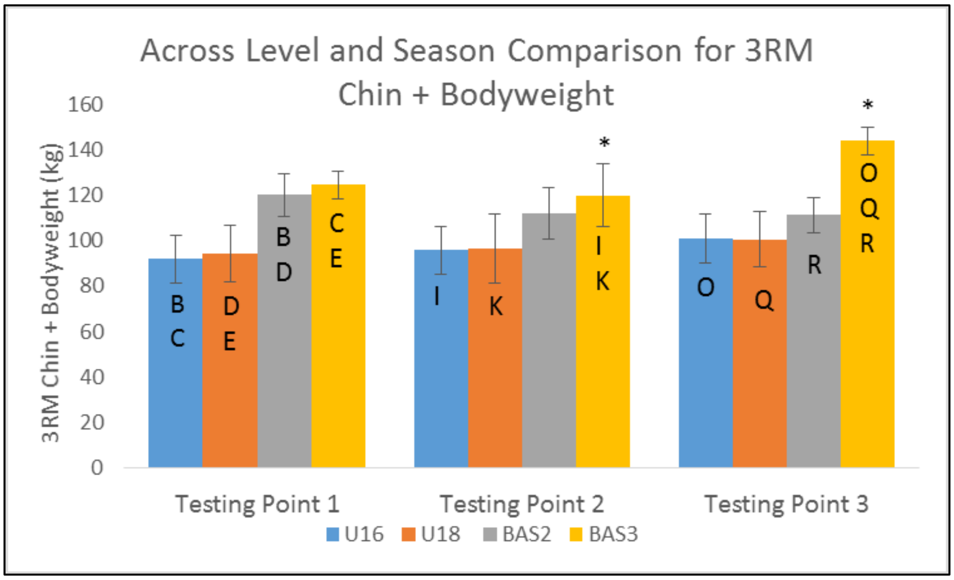



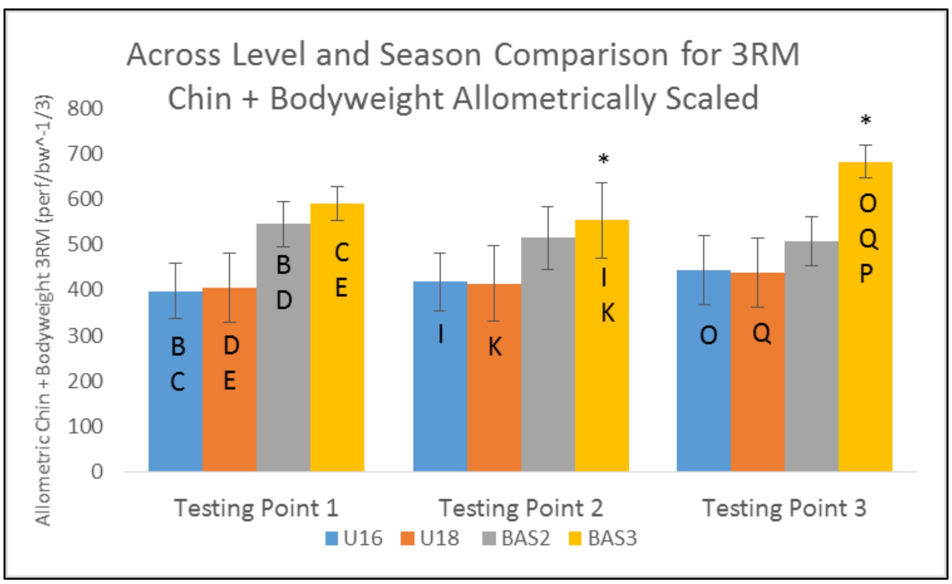
### 8.6.4 Whole Squad Cross Level and Seasonal Strength Testing Data Comparison Graphs Continued



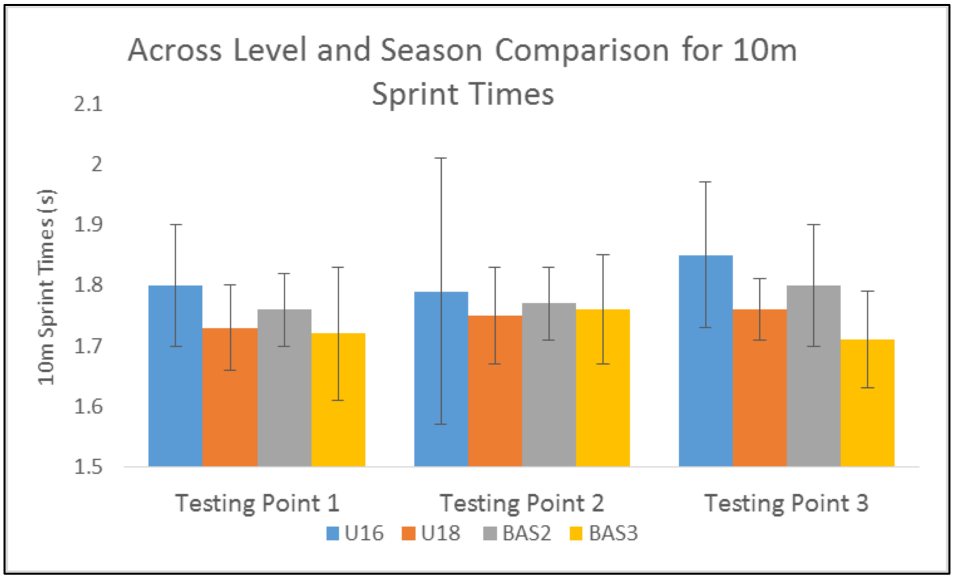



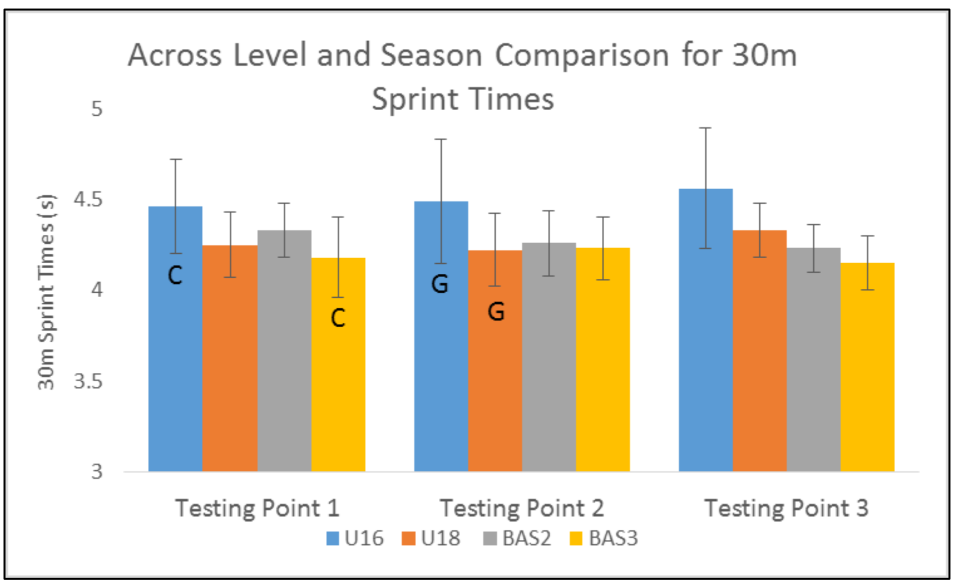
**8.6.4 Whole Squad Cross Level and Seasonal Strength Testing Data Comparison Graphs Continued**



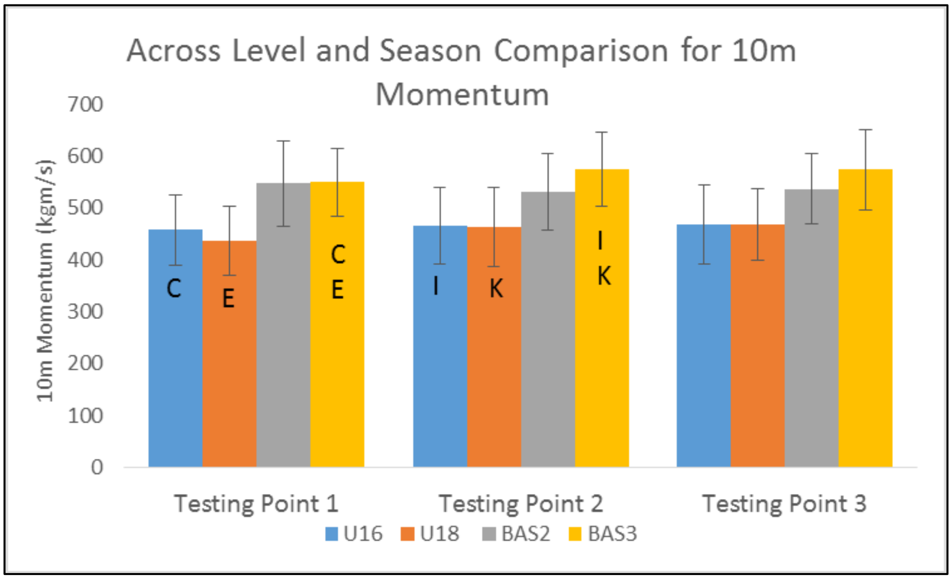



### 8.6.5 Whole Squad Cross Level and Seasonal Speed Testing Data Comparison Graphs

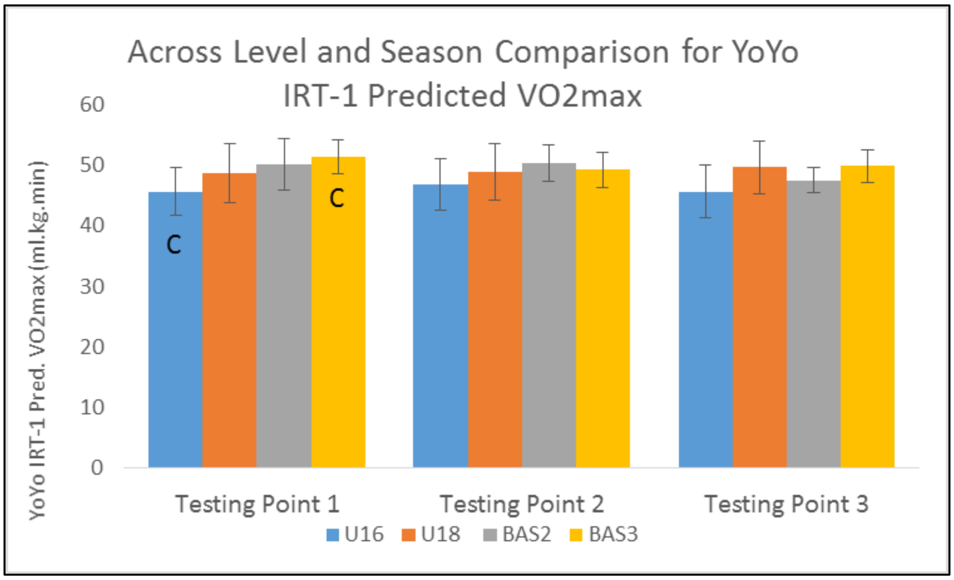


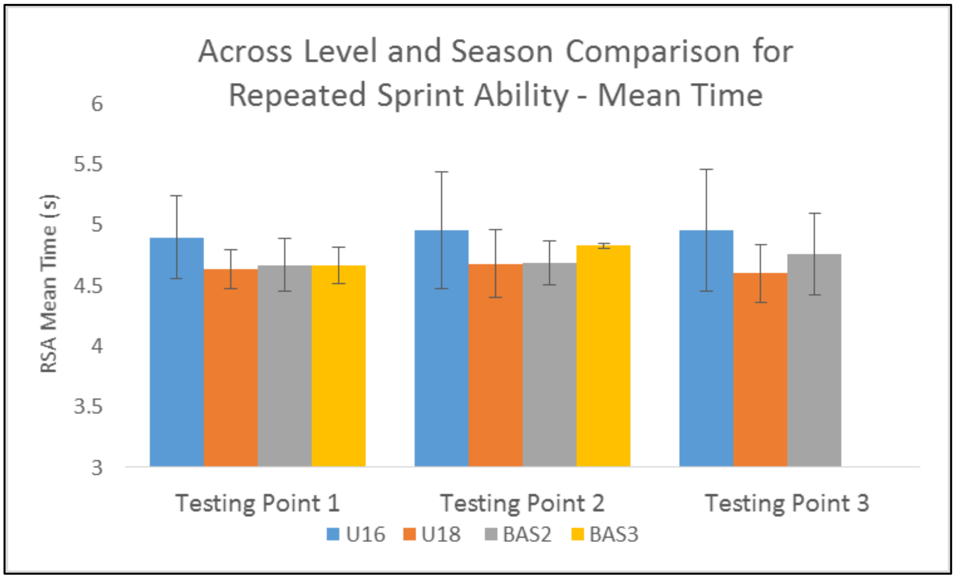
### 8.6.5 Whole Squad Cross Level and Seasonal Speed Testing Data Comparison Graphs Continued

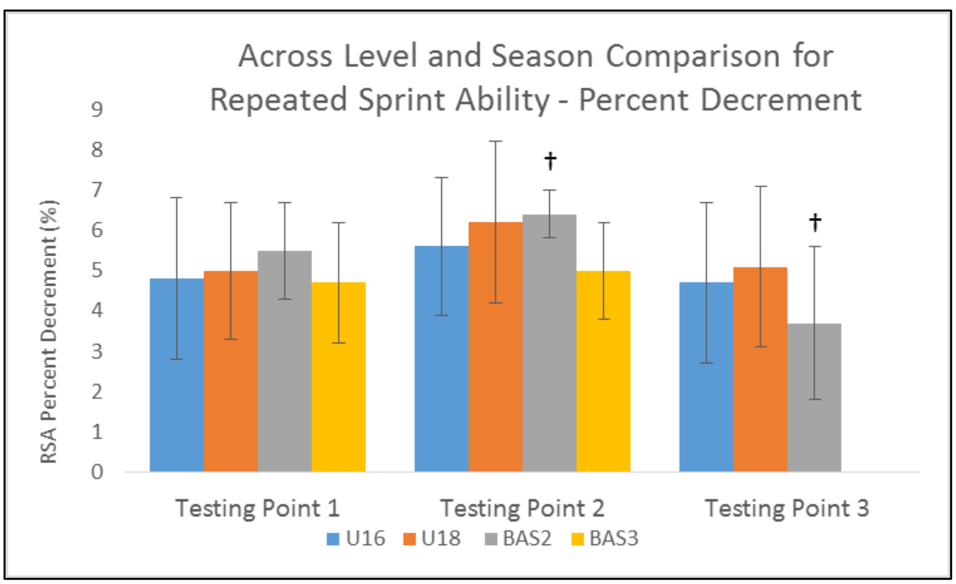


### 8.6.6 Whole Squad Cross Level and Seasonal Aerobic Fitness Testing Data Comparison Graphs

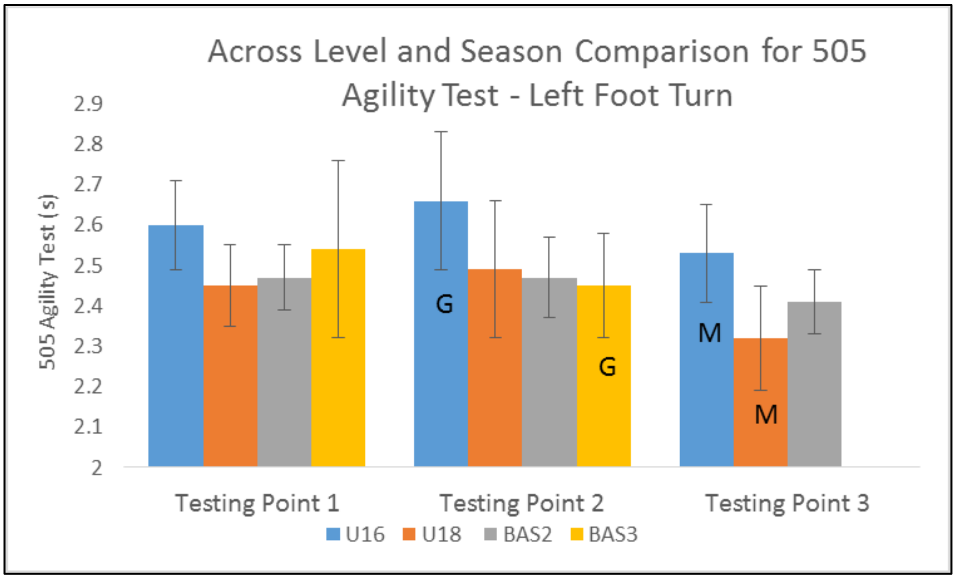


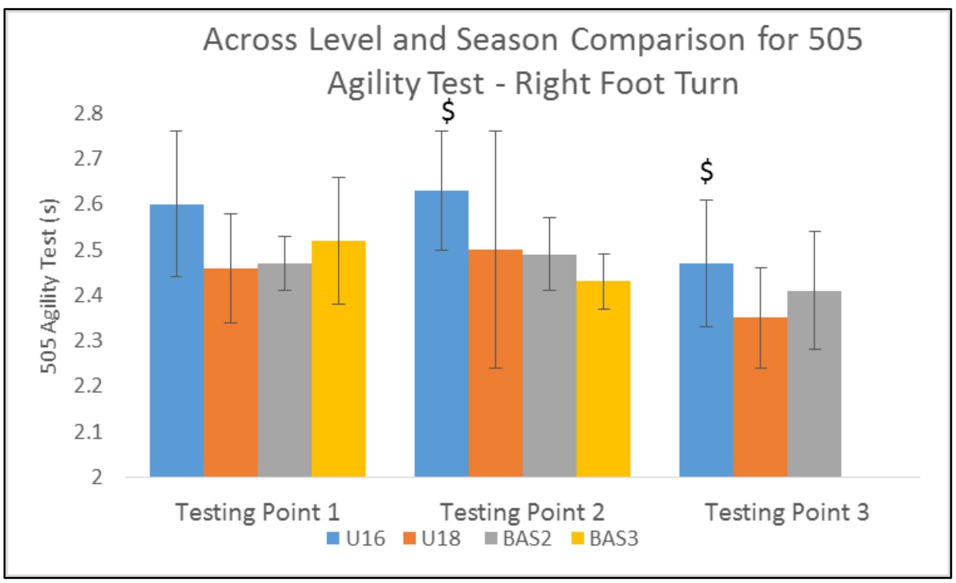
### 8.6.7 Whole Squad Cross Level and Seasonal Anaerobic Fitness Testing Data Comparison Graphs



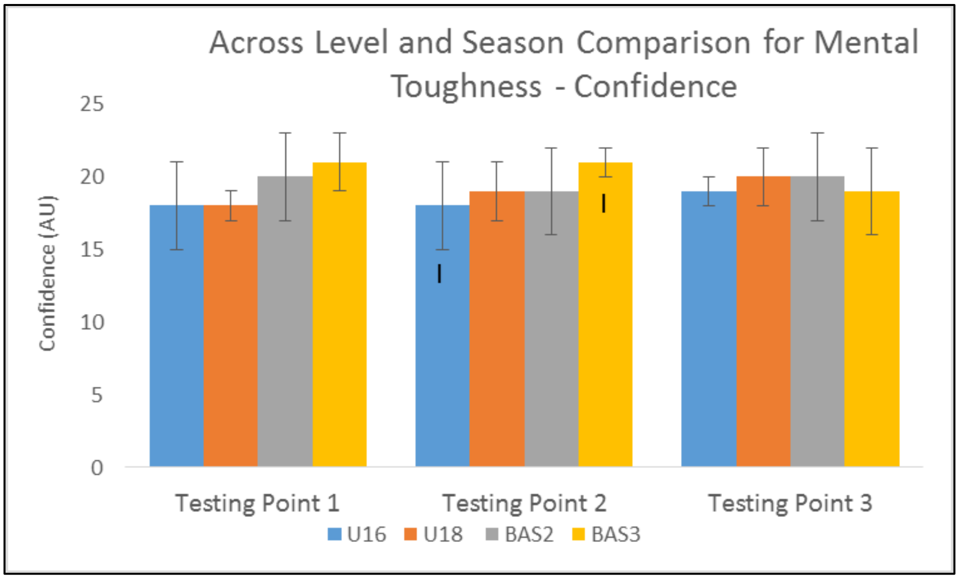



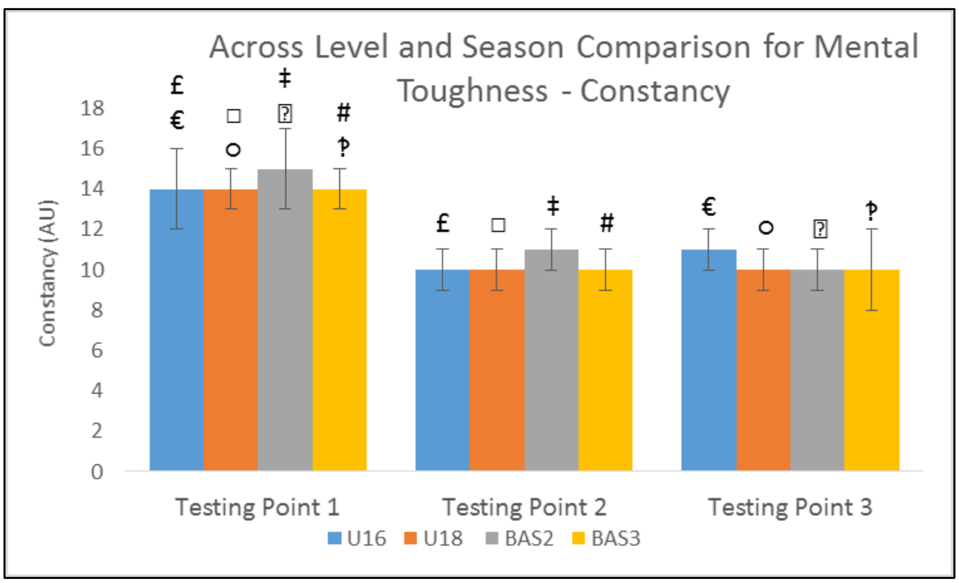
### 8.6.8 Whole Squad Cross Level and Seasonal Agility Testing Data Comparison Graphs



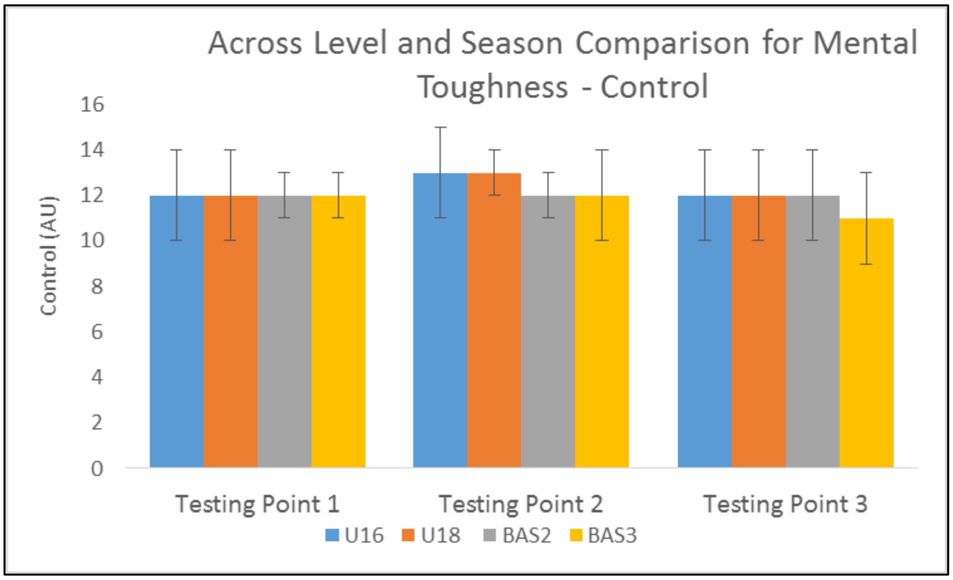



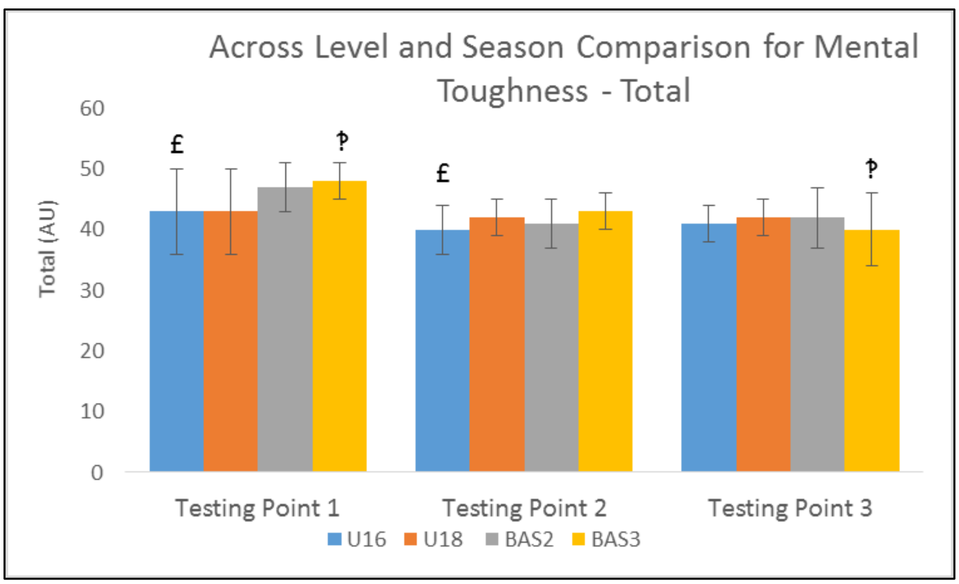
### 8.6.9 Whole Squad Cross Level and Seasonal Psychological Testing Data Comparison Graphs



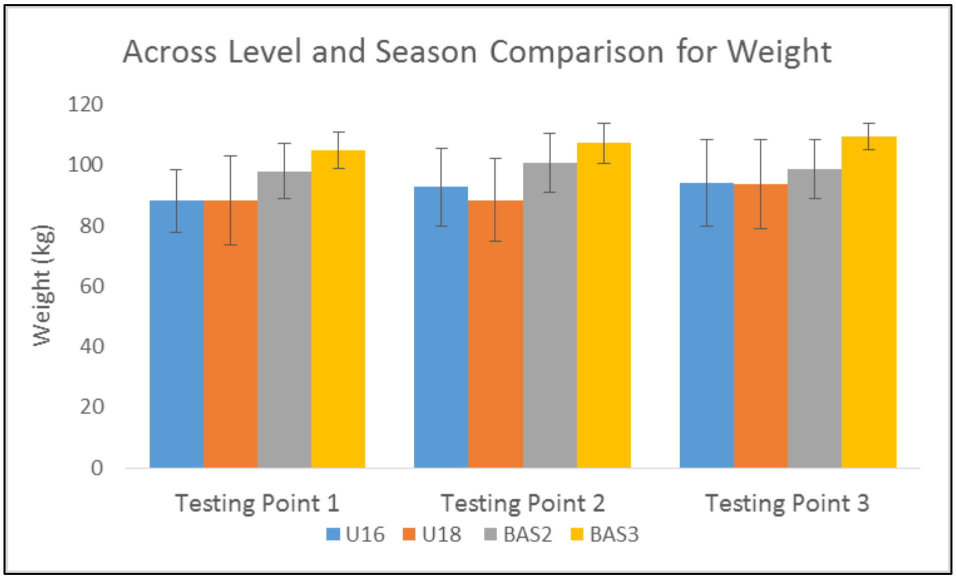
### 8.6.9 Whole Squad Cross Level and Seasonal Psychological Testing Data Comparison Graphs Continued

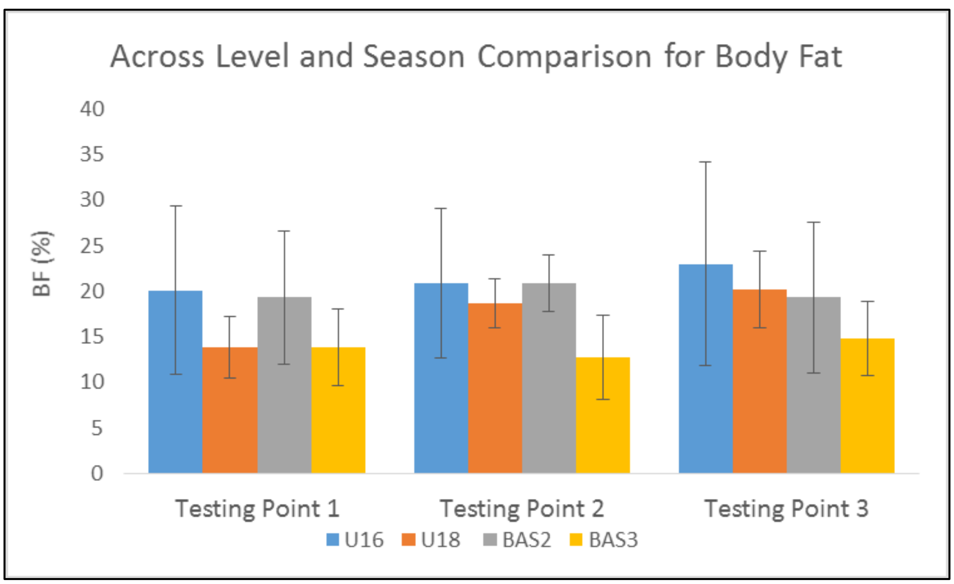


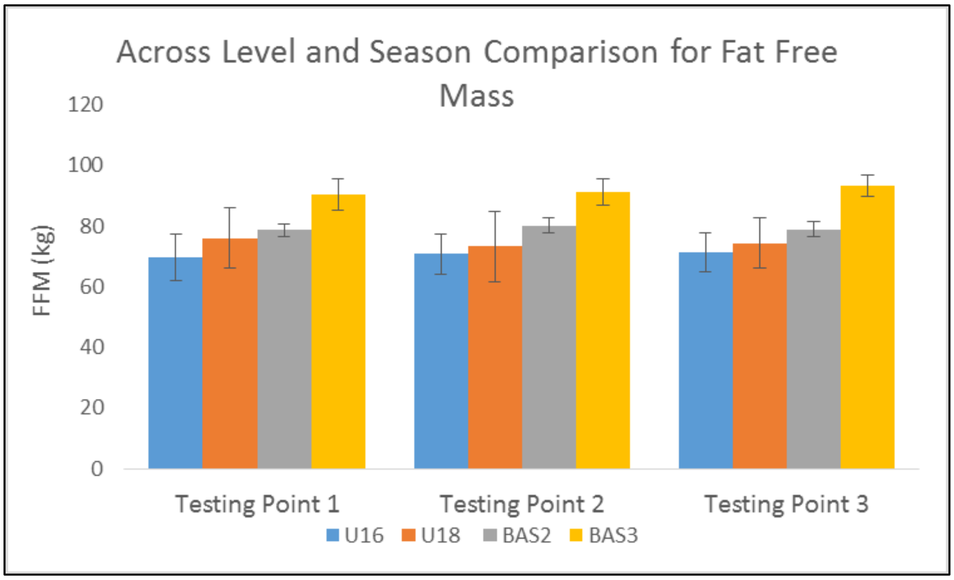
## 8.7 Forward Data Comparison Graphs

### 8.7.1 Forwards Cross Level and Seasonal Anthropometric Testing Data Comparison Graphs

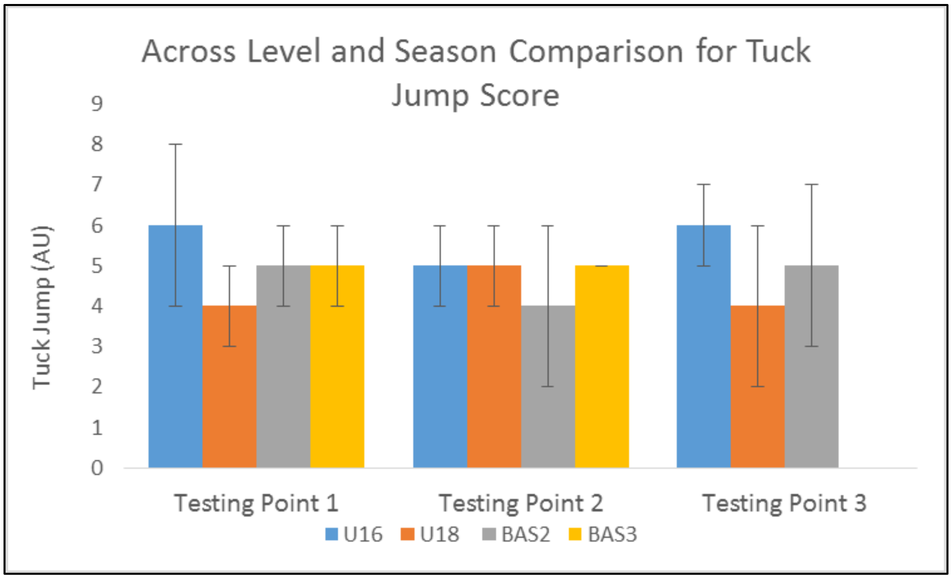


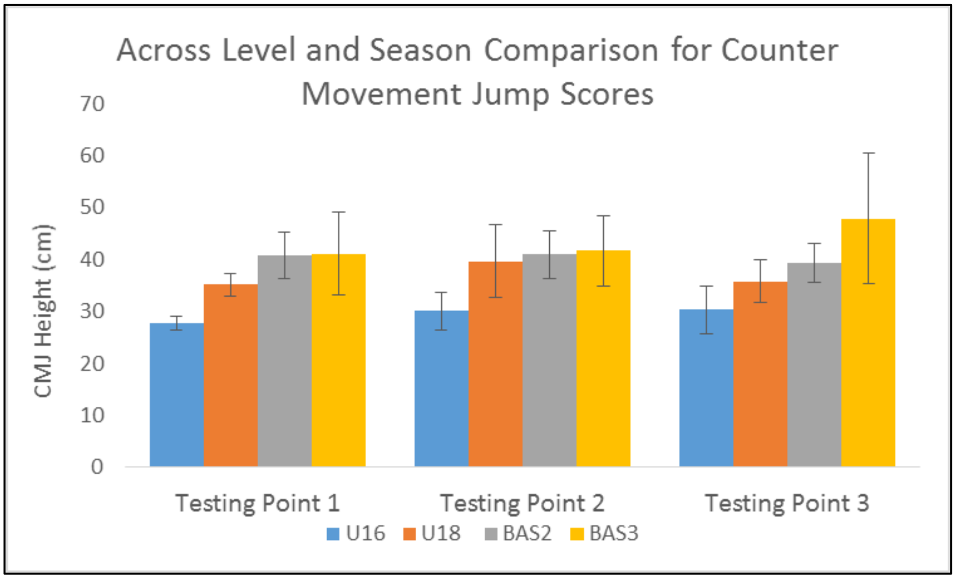
### 8.7.1 Forwards Cross Level and Seasonal Anthropometric Testing Data Comparison Graphs Continued



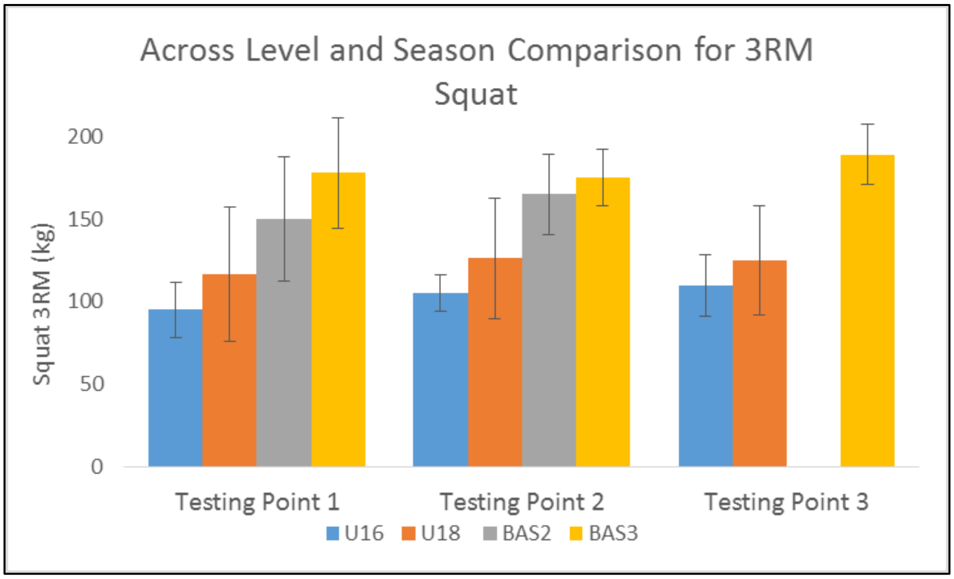
**8.7.2 Forwards Cross Level and Seasonal Functional Movement Data Comparison Graph**

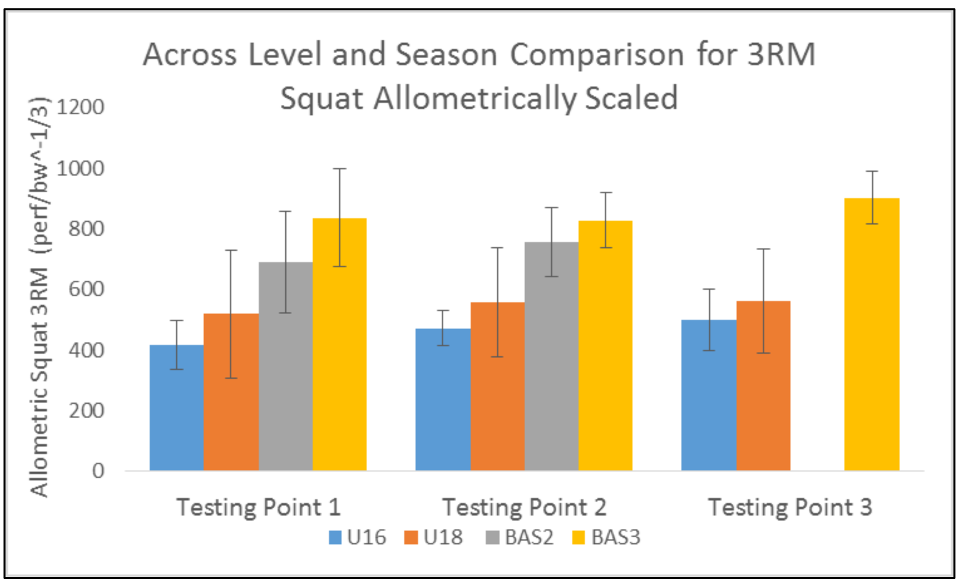


### 8.7.3 Forwards Cross Level and Seasonal Lower Body Power Testing Data Comparison Graphs

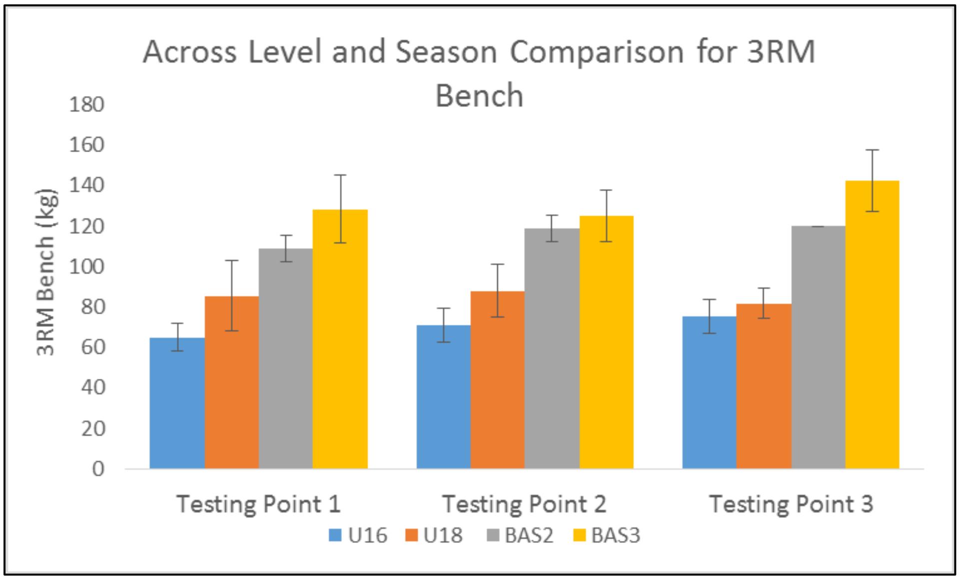


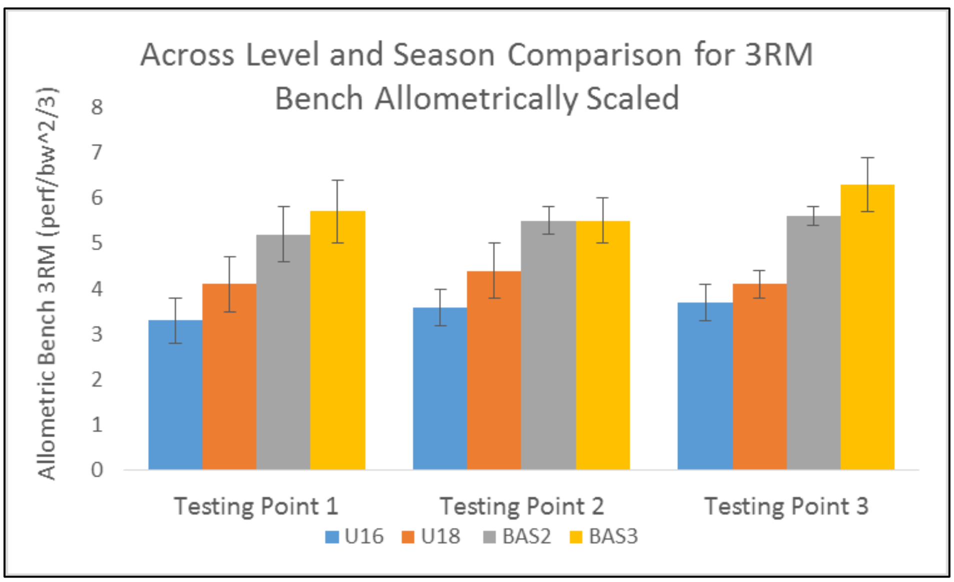
### 8.7.4 Forwards Cross Level and Seasonal Strength Testing Data Comparison Graphs



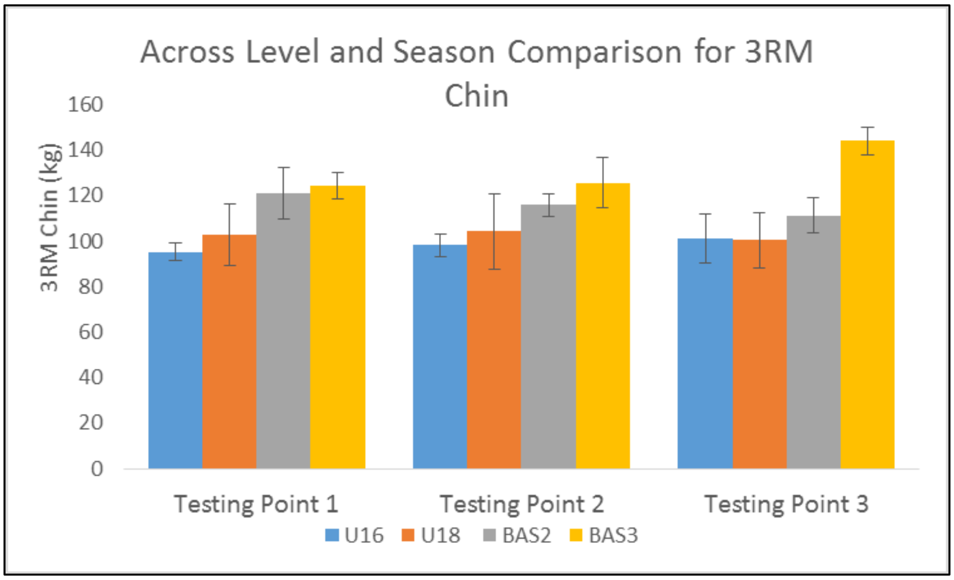



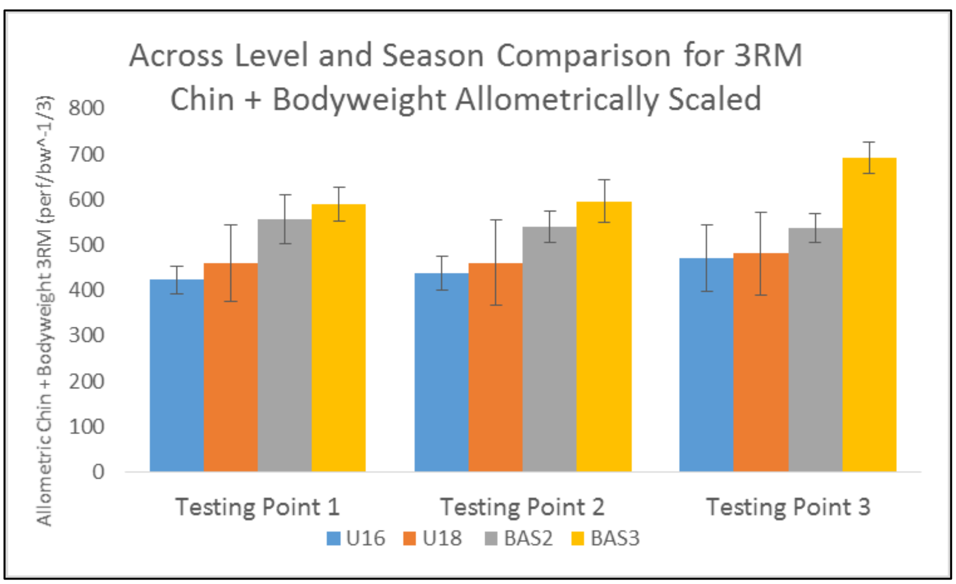
**8.7.4 Forwards Cross Level and Seasonal Strength Testing Data Comparison Graphs Continued**



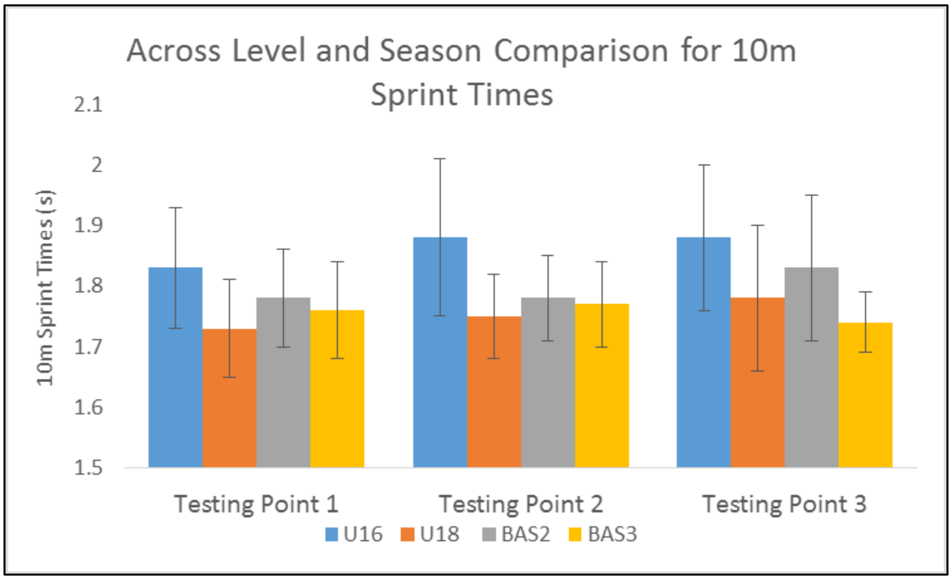



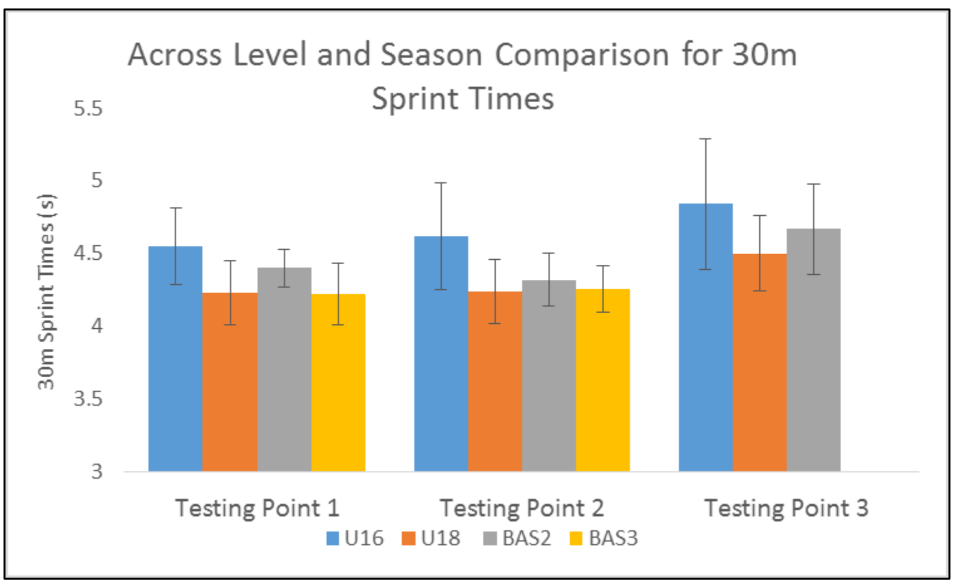
### 8.7.4 Forwards Cross Level and Seasonal Strength Testing Data Comparison Graphs Continued



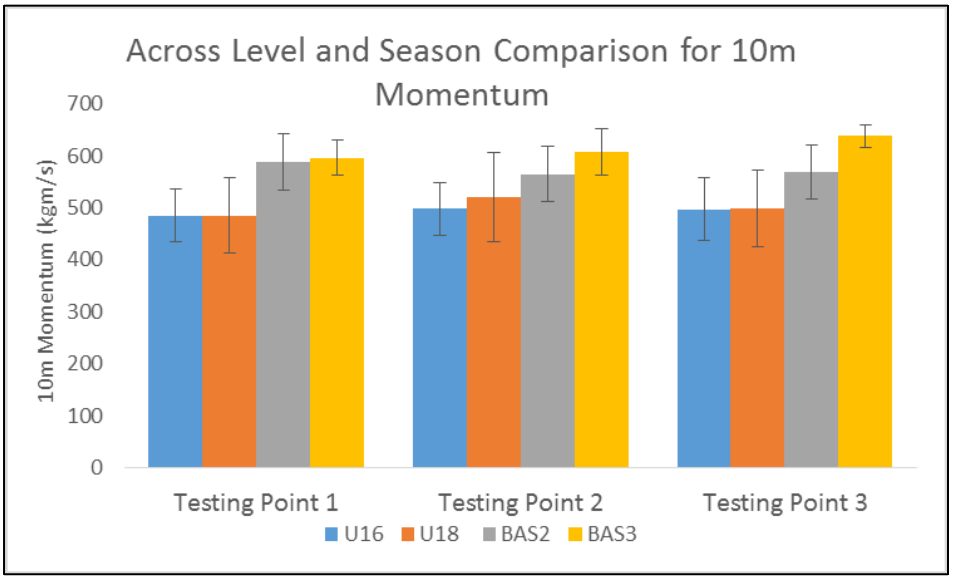



### 8.7.5 Forwards Cross Level and Seasonal Speed Testing Data Comparison Graphs

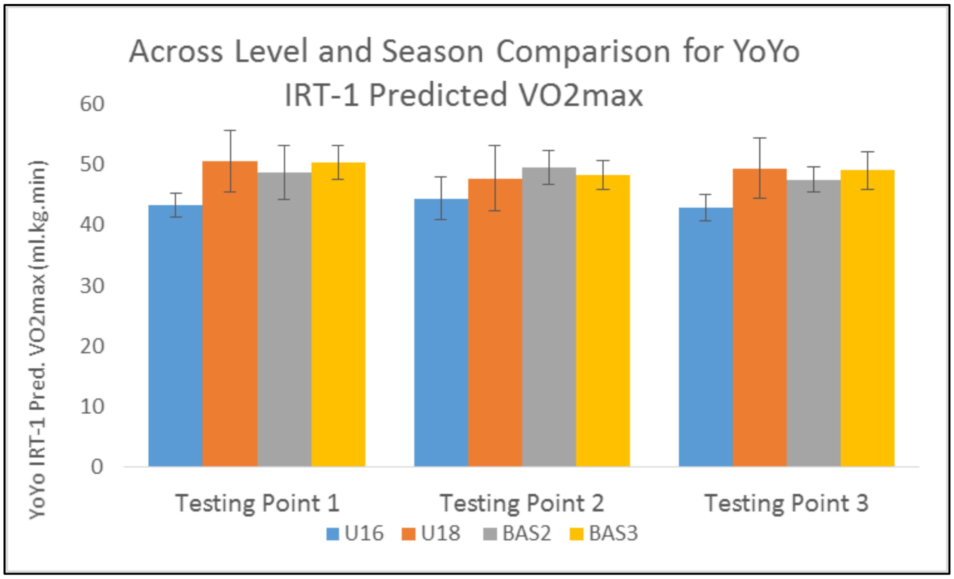


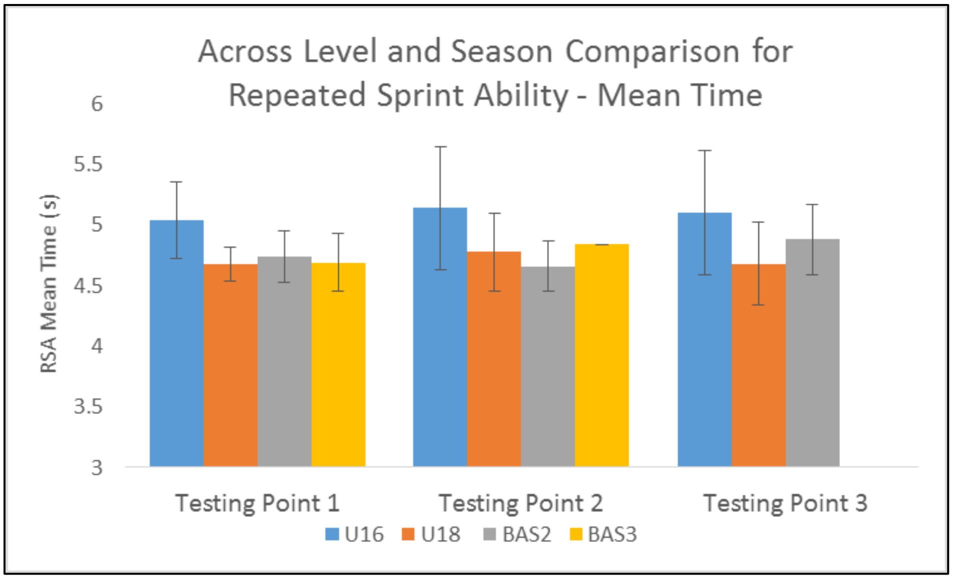
### 8.7.5 Forwards Cross Level and Seasonal Speed Testing Data Comparison Graphs Continued

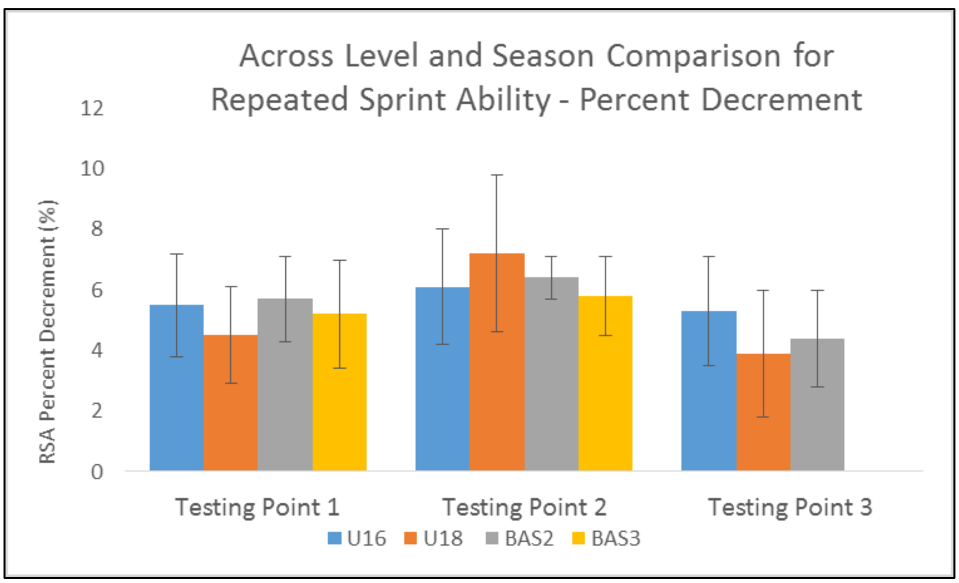


### 8.7.6 Forwards Cross Level and Seasonal Aerobic Fitness Testing Data Comparison Graphs

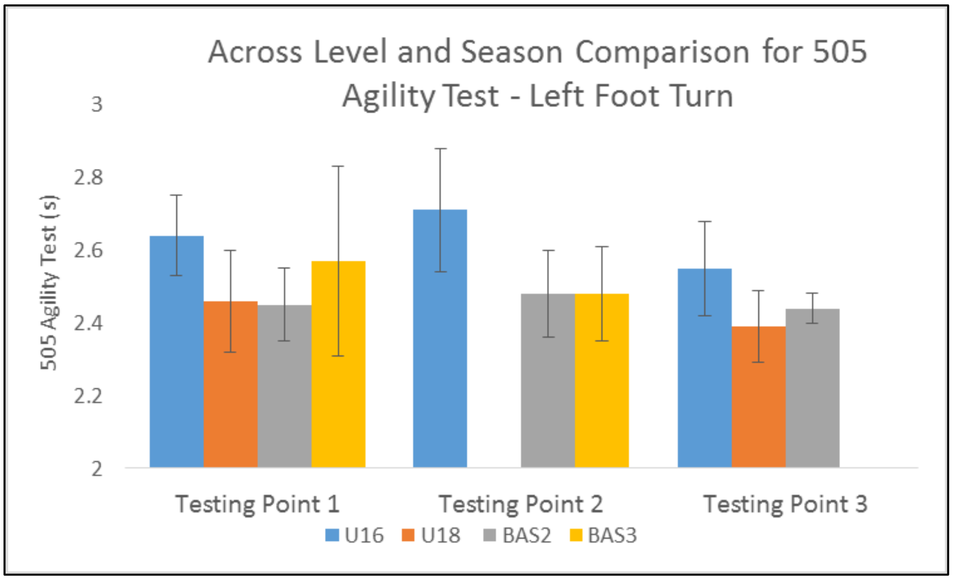


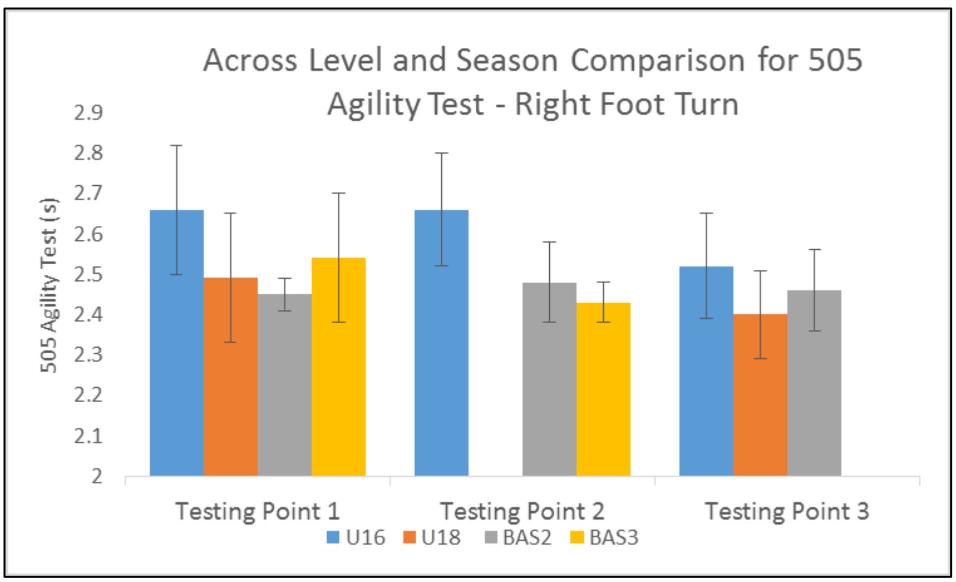
### 8.7.7 Forwards Cross Level and Seasonal Anaerobic Fitness Testing Data Comparison Graphs



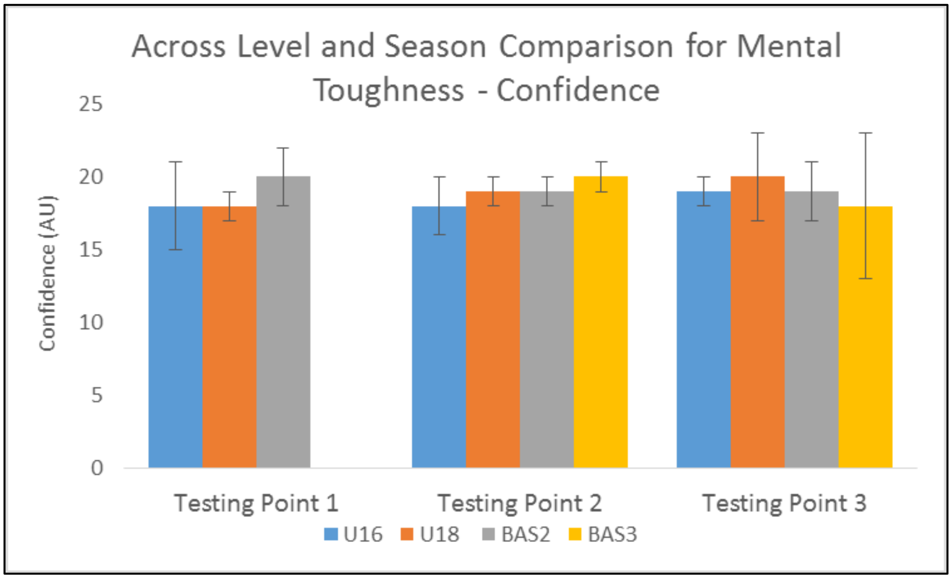



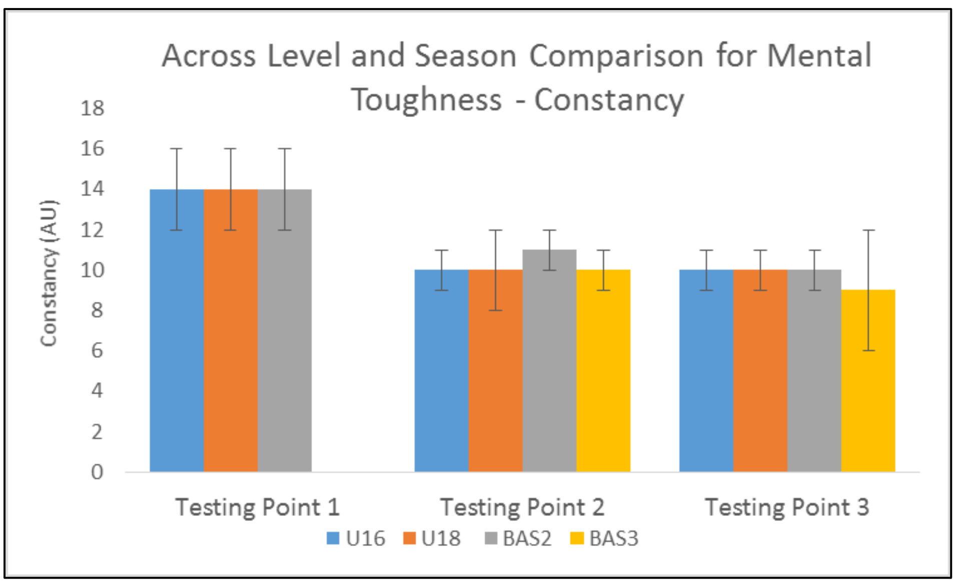
### 8.7.8 Forwards Cross Level and Seasonal Agility Testing Data Comparison Graphs



**8.7.9 Forwards Cross Level and Seasonal Psychological Testing Data Comparison Graphs**



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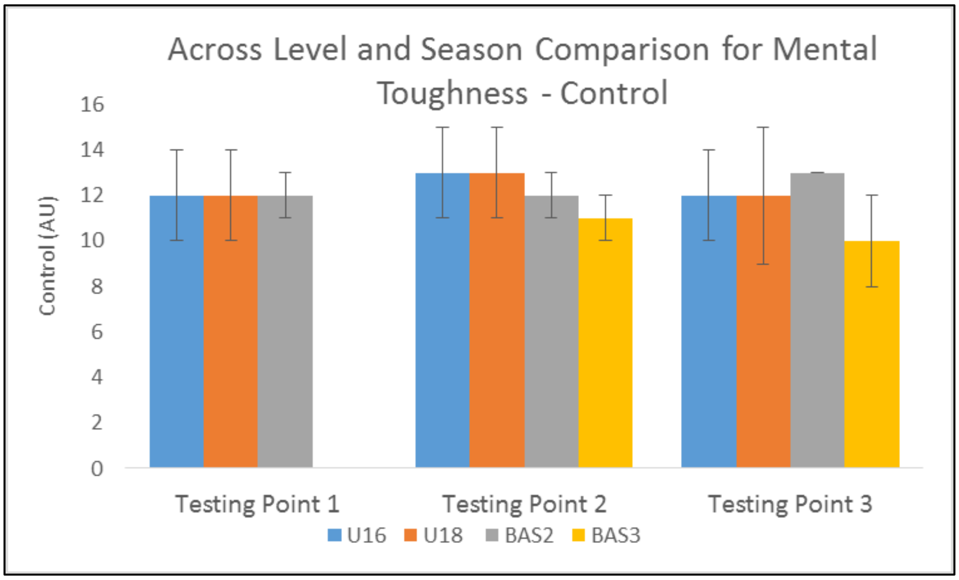
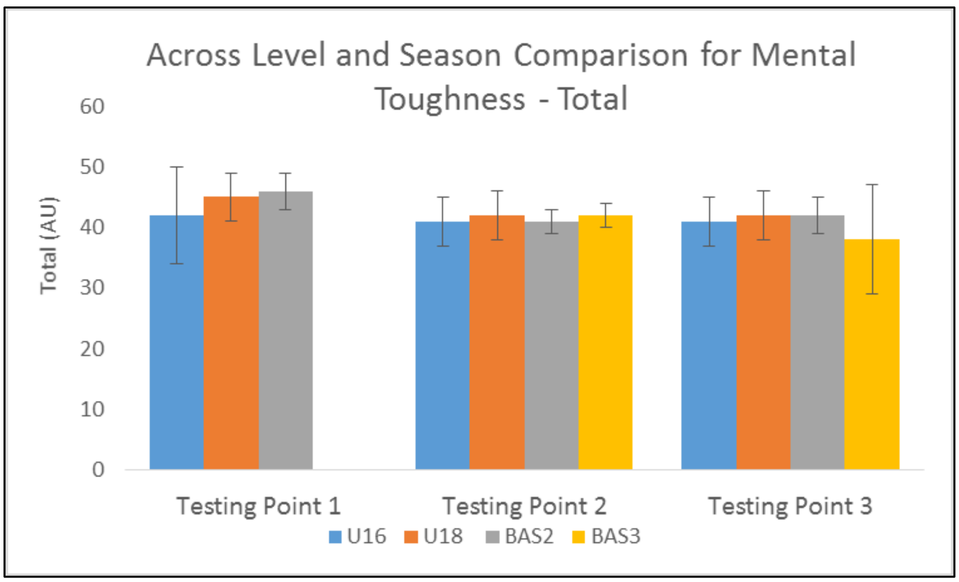
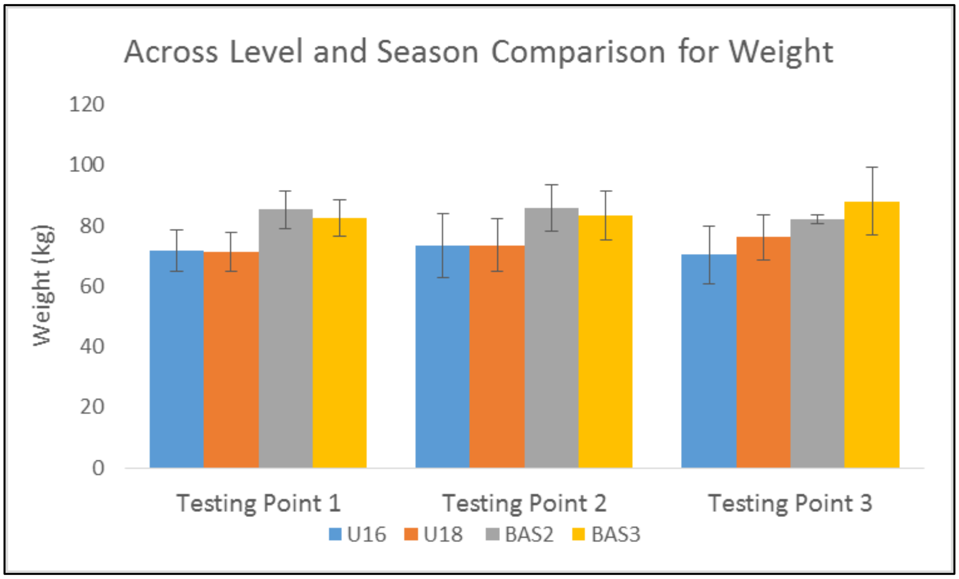
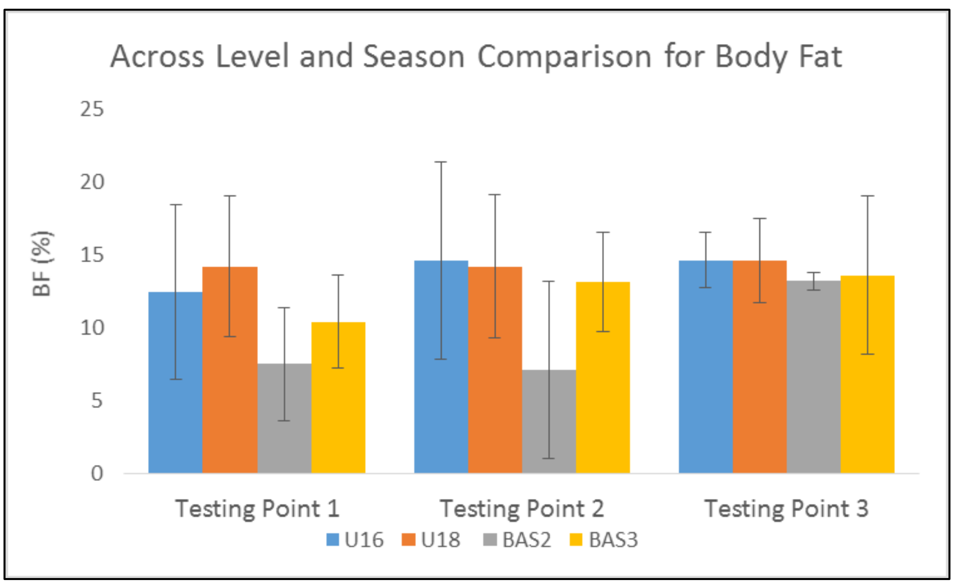


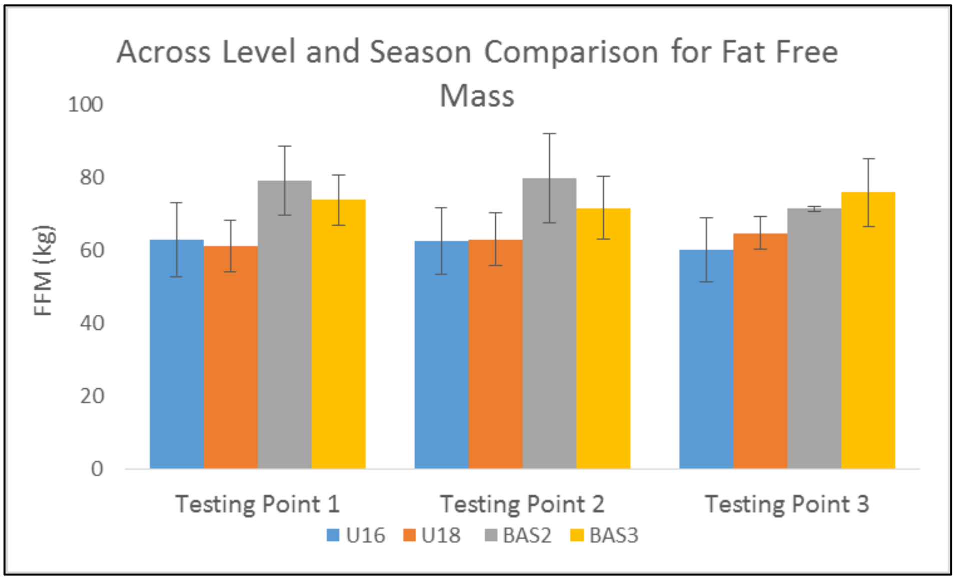
## 8.8 Back Data Comparison Graphs

### 8.8.1 Backs Cross Level and Seasonal Anthropometric Testing Data Comparison Graphs

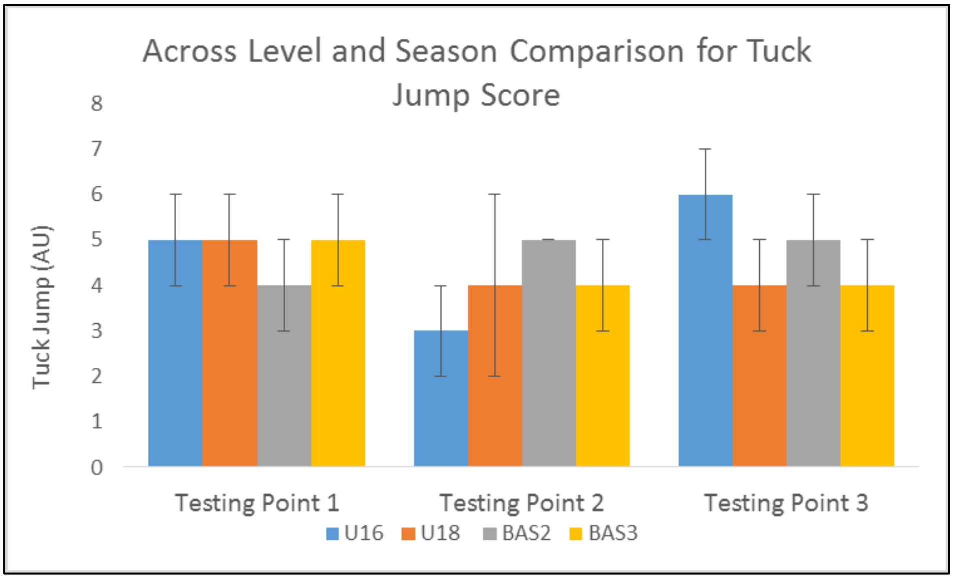


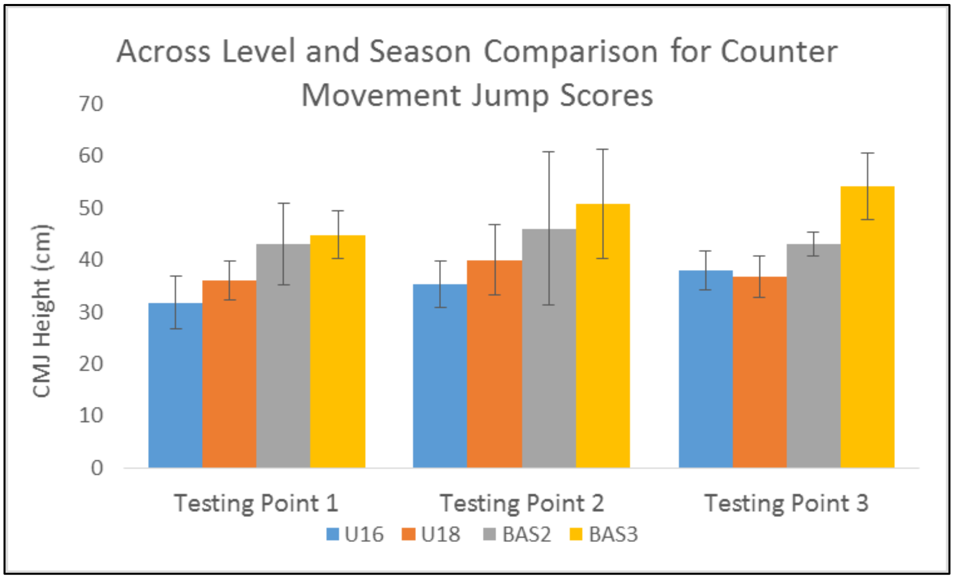
## 8.8.1 Backs Cross Level and Seasonal Anthropometric Testing Data Comparison Graphs Continued



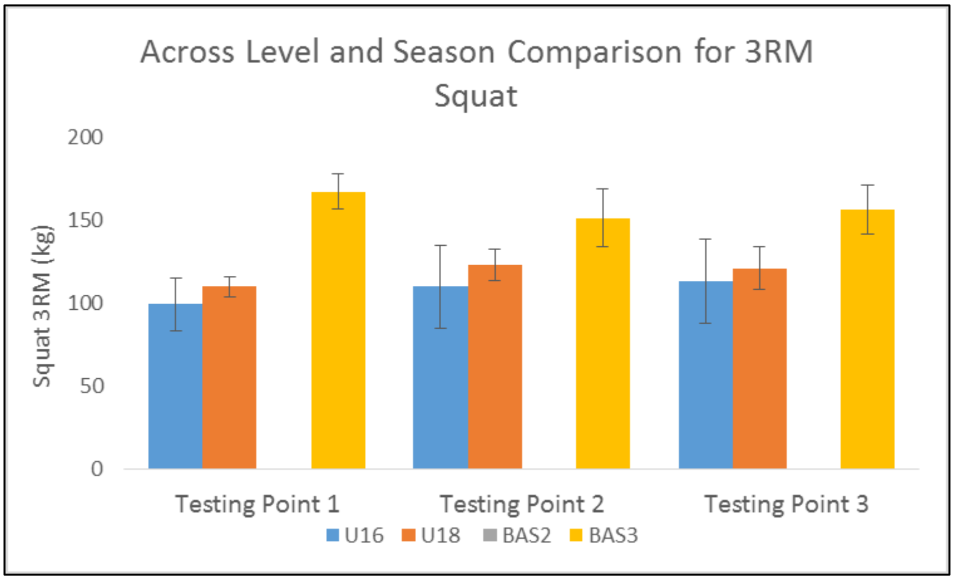
### 8.8.2 Backs Cross Level and Seasonal Functional Movement Data Comparison Graphs

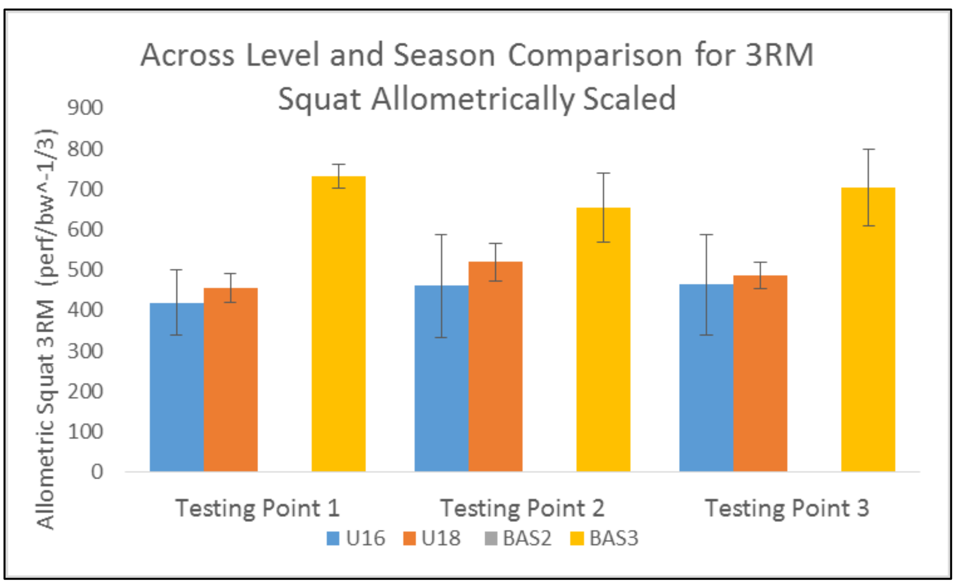


### 8.8.3 Backs Cross Level and Seasonal Lower Body Power Testing Data Comparison Graphs

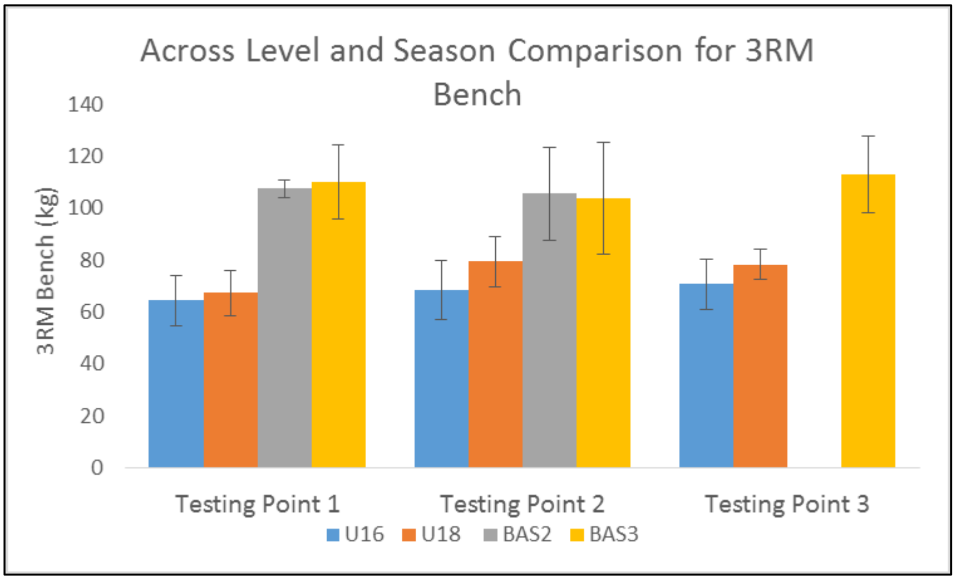


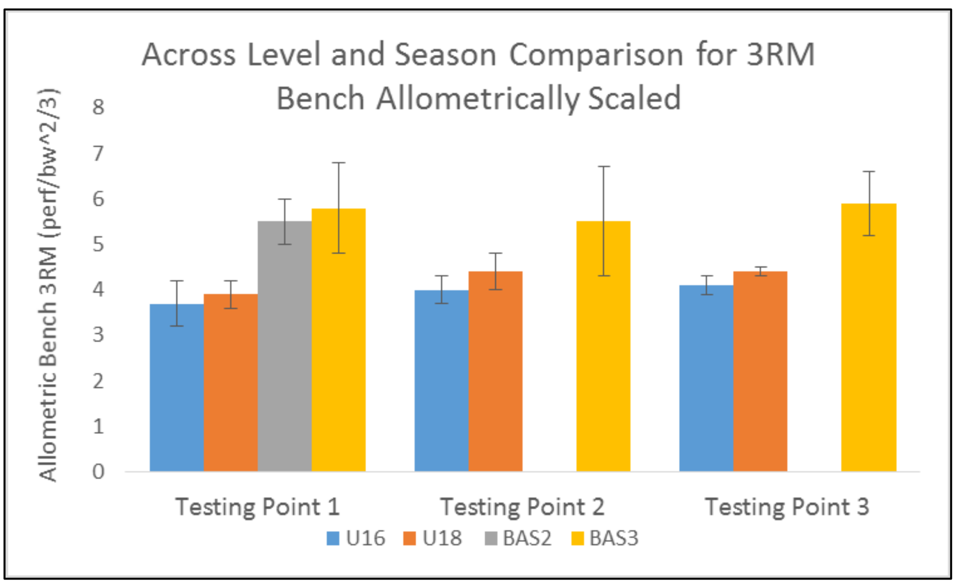
### 8.8.4 Backs Cross Level and Seasonal Strength Testing Data Comparison Graphs



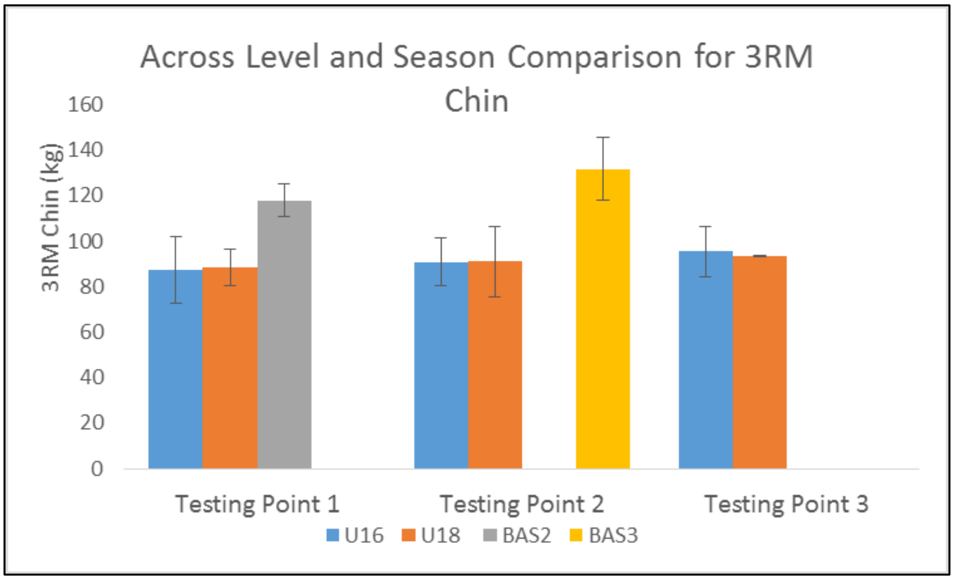



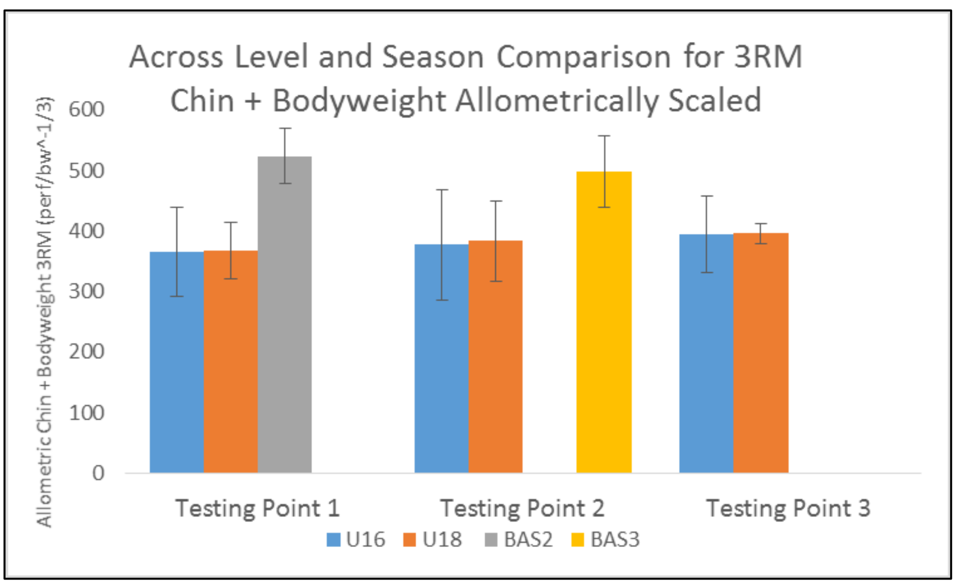
**8.8.4 Backs Cross Level and Seasonal Strength Testing Data Comparison Graphs Continued**



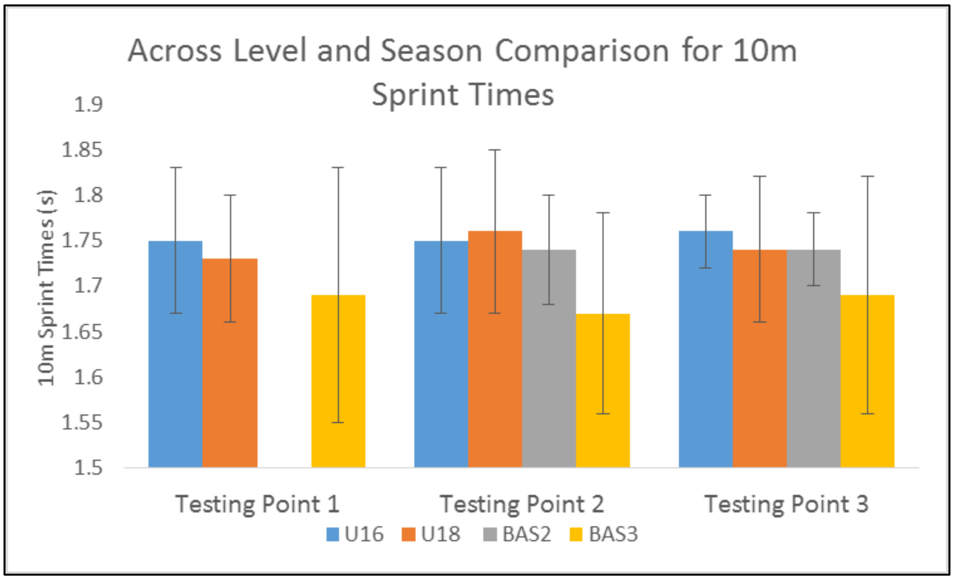



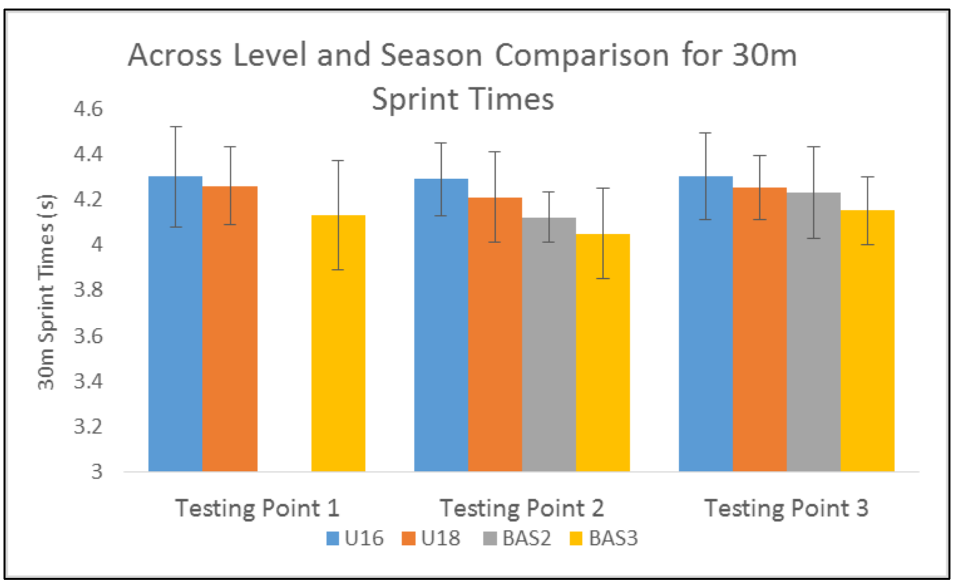
### 8.8.4 Backs Cross Level and Seasonal Strength Testing Data Comparison Graphs Continued



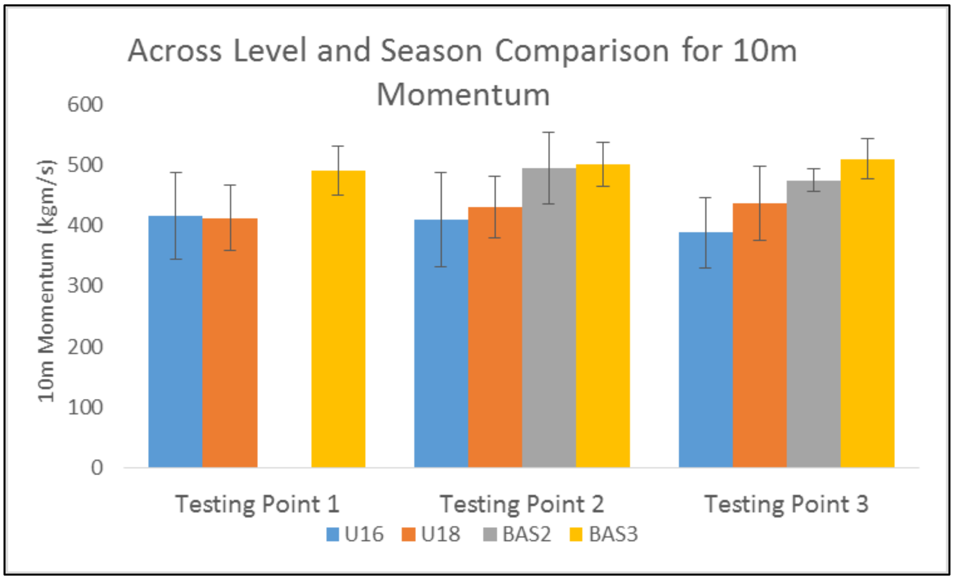



### 8.8.5 Backs Cross Level and Seasonal Speed Testing Data Comparison Graphs

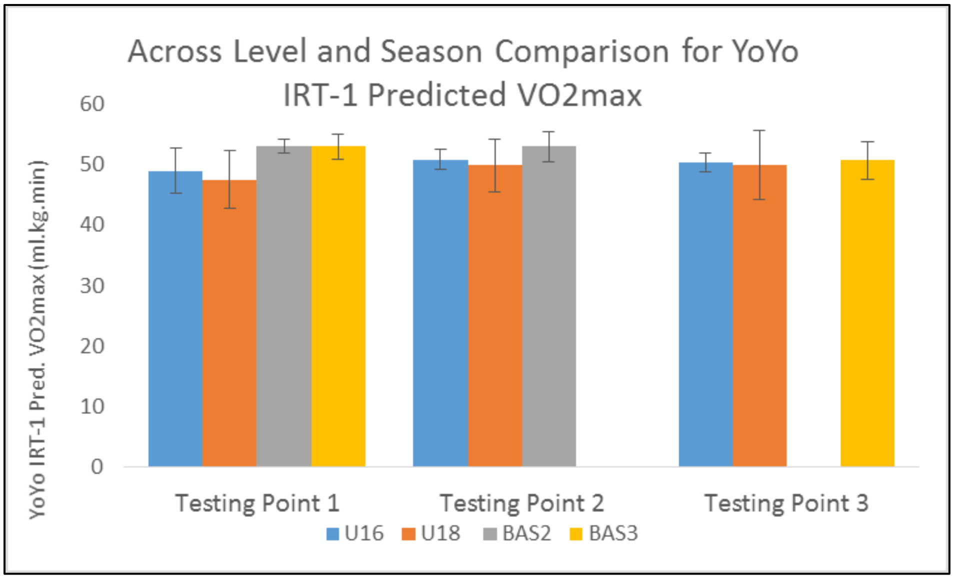


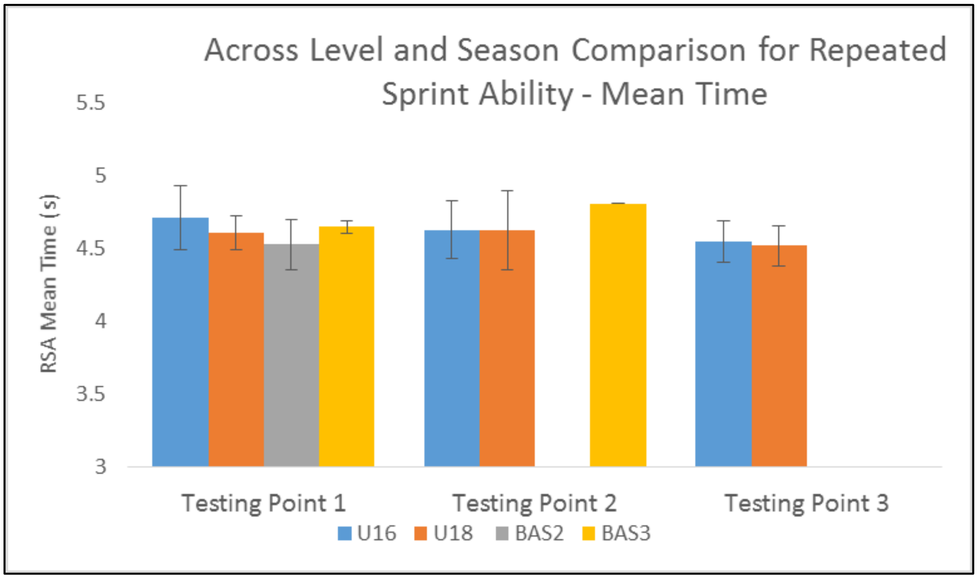
### 8.8.5 Backs Cross Level and Seasonal Speed Testing Data Comparison Graphs Continued

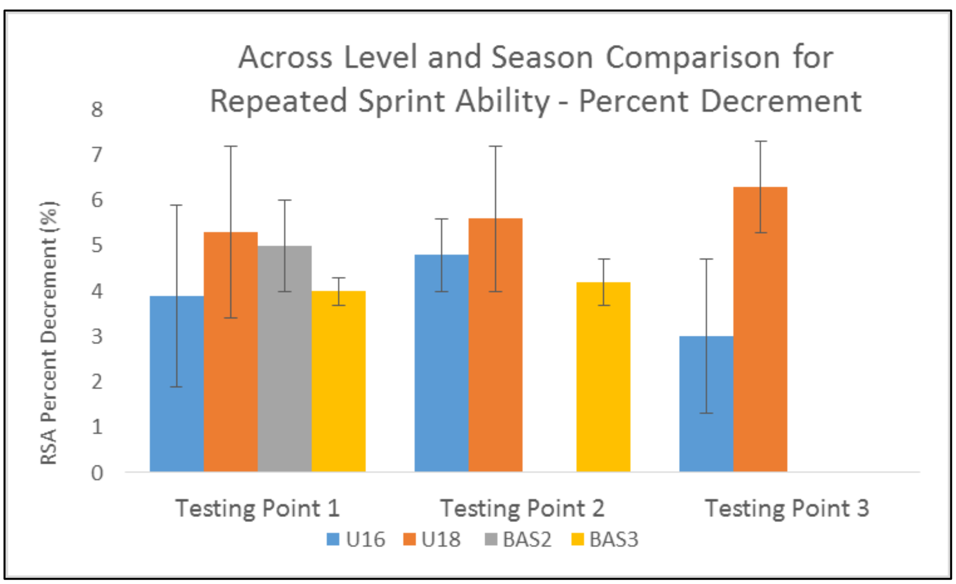


### 8.8.6 Backs Cross Level and Seasonal Aerobic Fitness Testing Data Comparison Graphs

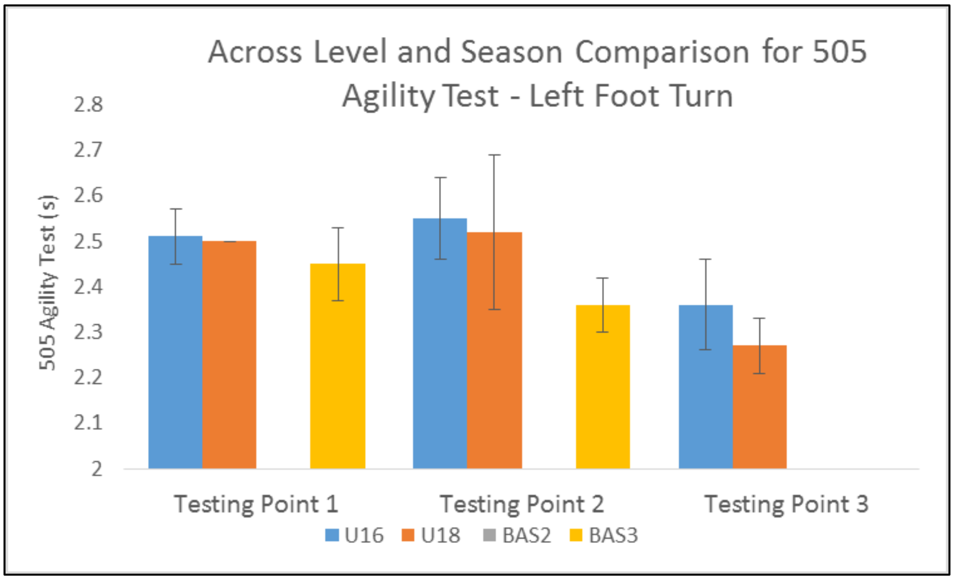


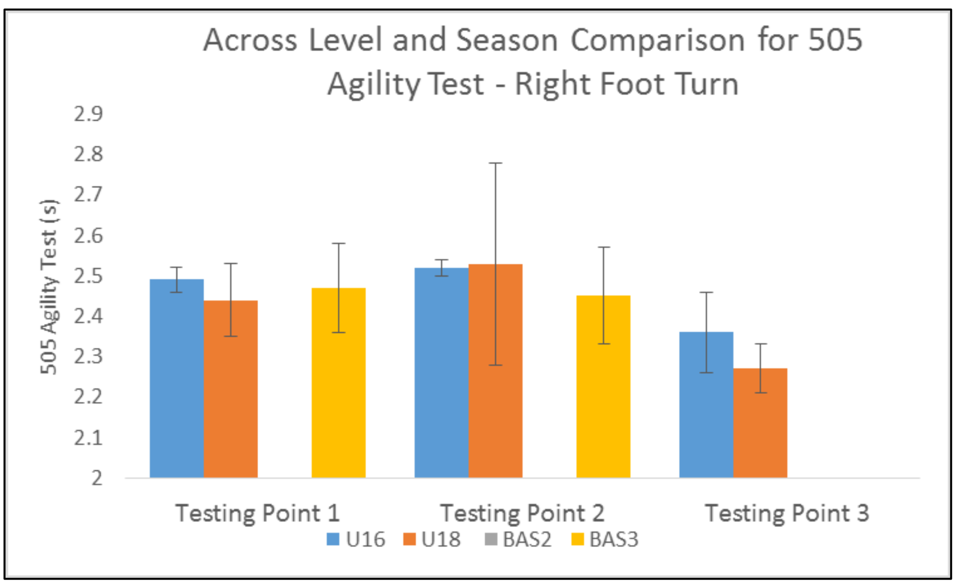
### 8.8.7 Backs Cross Level and Seasonal Anaerobic Fitness Testing Data Comparison Graphs



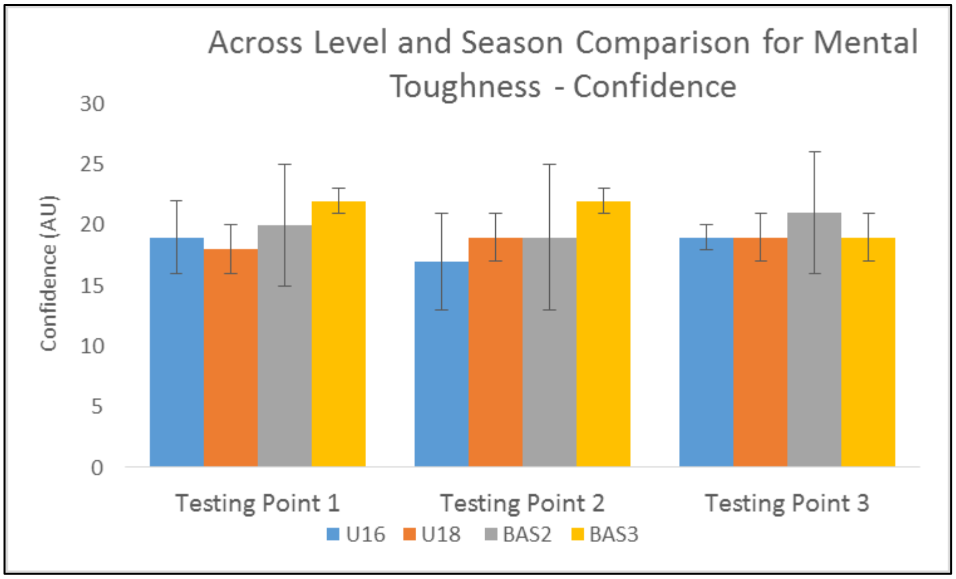



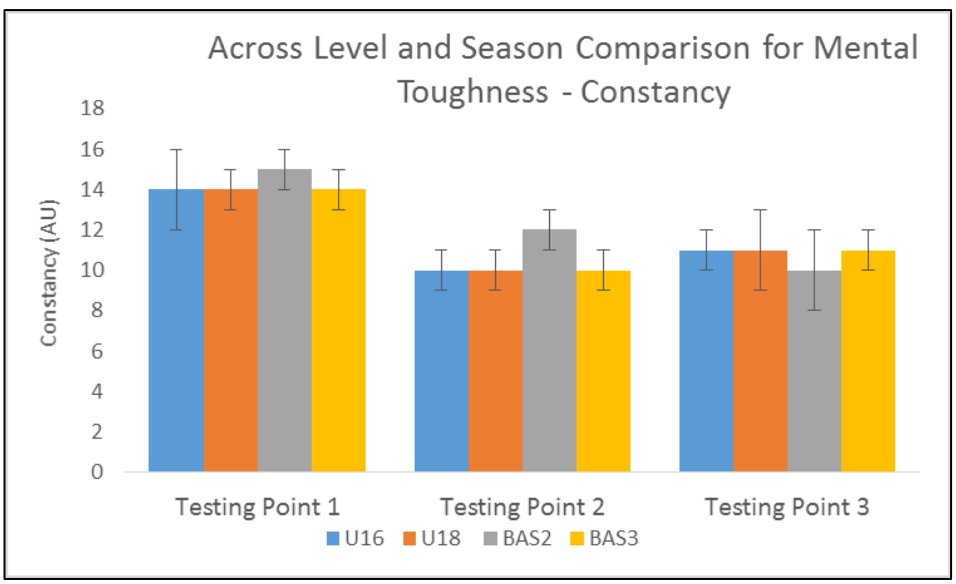
### 8.8.8 Backs Cross Level and Seasonal Agility Testing Data Comparison Graphs



### 8.8.9 Backs Cross Level and Seasonal Psychological Testing Data Comparison Graphs



## 8.8.9 Backs Cross Level and Seasonal Psychological Testing Data Comparison Graphs Continued