

**UNIVERSITY of
STIRLING**



**Towards a Better Understanding of the Value of Physical Fitness Testing
within the Identification and Development of Youth Soccer Players**

James H. Dugdale, BSc (Hons), MSc

A thesis submitted to the University of Stirling in partial fulfilment for the degree of

Doctor of Philosophy

Physiology, Exercise and Nutrition Research Group, Faculty of Health Sciences and Sport

May 2019

"It always seems impossible until it's done"

Nelson Mandela

DECLARATION

I declare that the contents of this thesis are entirely my own work, and that the document was composed by myself under the supervision of Dr. Angus M. Hunter, Dr. Dajo Sanders, Dr. Calum A. Arthur, and with statistical assistance from Dr. Tony Myers. Assistance during data collection was provided by University of Stirling undergraduate and postgraduate students during Chapter's 3 and 4, and from the Forth Valley Football Academy sport science department (2006-2015) during Chapter 6. The experimental studies within this thesis were all approved by the University of Stirling cross-faculty ethics committees, and procedures were conducted as they were approved. Neither the thesis, nor the original work within have been submitted to this or any other institution towards a higher degree. This thesis does not infringe upon anyone's copyright and any material from the work of others included in this thesis are fully acknowledged in accordance with common reference practices.

Signed:



James H. Dugdale

Stirling

May 2019

The copyright of this thesis belongs to the author, under the terms of the United Kingdom copyright act, as qualified by the University of Stirling regulations. Due acknowledgement must always be made to the author when using any materials contained in, or derived from this thesis.

TABLE OF CONTENTS

I – ACKNOWLEDGEMENTS	1
II – PUBLICATIONS	3
III – GENERAL ABSTRACT	4
IV – LIST OF FIGURES	6
V – LIST OF TABLES	8
VI – LIST OF ABBREVIATIONS	10
<u>CHAPTER 1 – INTRODUCTION</u>	<u>12</u>
1.1 Background	12
1.2 General aims of this thesis	16
1.3 Overview of thesis	17
<u>CHAPTER 2 – REVIEW OF LITERATURE</u>	<u>18</u>
2.1 Talent identification	19
<i>2.1.1 Talent identification in soccer</i>	19
<i>2.1.2 Talent development</i>	23
<i>2.1.3 Limitations of talent identification</i>	25
<i>2.1.3.1 The relative age effect</i>	26
<i>2.1.3.2 Maturation-selection phenomenon</i>	26
<i>2.1.3.3 Growth and maturation</i>	27
<i>2.1.3.4 Challenges of talent identification</i>	28
<i>2.1.4 Limitations of talent development</i>	30
<i>2.1.5 Talent identification – summary</i>	31

2.2 Physical characteristics of soccer	33
2.2.1 <i>Physical characteristics of professional soccer</i>	34
2.2.1.1 <i>Running characteristics of professional soccer</i>	35
2.2.1.2 <i>Strength and power characteristics of professional soccer</i>	37
2.2.1.3 <i>Anthropometric and morphologic characteristics of professional soccer</i>	39
2.2.1.4 <i>Physical characteristics of professional soccer – summary</i>	41
2.2.2 <i>Physical characteristics of youth soccer</i>	42
2.2.2.1 <i>Running characteristics of youth soccer</i>	44
2.2.2.2 <i>Strength and power characteristics of youth soccer</i>	48
2.2.2.3 <i>Anthropometric and morphologic characteristics of youth soccer</i>	50
2.2.2.4 <i>Physical characteristics of youth soccer – summary</i>	54
2.2.3 <i>Physical characteristics of soccer – summary</i>	55
2.3 Physical performance testing in soccer	57
2.3.1 <i>Evaluating running characteristics of soccer</i>	58
2.3.1.1 <i>Evaluating running characteristics of soccer – endurance</i>	58
2.3.1.2 <i>Evaluating running characteristics of soccer – linear sprint speed</i>	63
2.3.1.3 <i>Evaluating running characteristics of soccer – COD/agility</i>	66
2.3.2 <i>Evaluating strength and power characteristics of soccer</i>	70
2.3.2.1 <i>Evaluating strength characteristics of soccer</i>	71

2.3.2.2 <i>Evaluating power characteristics of soccer</i>	73
2.3.3 <i>Evaluating anthropometric and morphologic characteristics of soccer</i>	77
2.3.4 <i>Physical performance testing in soccer – summary</i>	80
2.4 Physical performance testing for talent identification and development	82
2.4.1 <i>Physical performance testing for talent identification</i>	82
2.4.2 <i>Physical performance testing for talent development</i>	87
2.5 Literature review – summary	88
2.6 Aims	89
VII – SYNTHESIS (LITERATURE REVIEW – CHAPTER 3)	90
<u>CHAPTER 3 – RELIABILITY AND VALIDITY OF COMMONLY USED FIELD-BASED FITNESS TESTS IN YOUTH SOCCER PLAYERS</u>	<u>91</u>
3.1 <i>Introduction</i>	92
3.2 <i>Methods</i>	95
3.3 <i>Results</i>	102
3.4 <i>Discussion</i>	109
3.5 <i>Conclusion</i>	113
VIII – SYNTHESIS (CHAPTER 3 – CHAPTER 4)	114
<u>CHAPTER 4 – CHANGE OF DIRECTION AND AGILITY PERFORMANCE ASSESSMENT IN PROFESSIONAL YOUTH SOCCER PLAYERS</u>	<u>115</u>
4.1 <i>Introduction</i>	116
4.2 <i>Methods</i>	119
4.3 <i>Results</i>	127

4.4 Discussion	136
4.5 Conclusion	139
IX – SYNTHESIS (CHAPTER 4 – CHAPTER 5)	140
<u>CHAPTER 5 – A COMPARISON OF OBJECTIVE AND SUBJECTIVE EVALUATION METHODS OF PHYSICAL QUALITIES IN PROFESSIONAL YOUTH SOCCER PLAYERS</u>	<u>141</u>
5.1 Introduction	142
5.2 Methods	144
5.3 Results	151
5.4 Discussion	161
5.5 Conclusion	164
X – SYNTHESIS (CHAPTER 5 – CHAPTER 6)	165
<u>CHAPTER 6 – IDENTIFYING PHYSICAL VARIABLES RELATED TO YOUTH-SENIOR PROGRESSION: A 12-YEAR REVIEW OF FITNESS TEST DATA IN ACADEMY YOUTH SOCCER</u>	<u>166</u>
6.1 Introduction	167
6.2 Methods	170
6.3 Results	174
6.4 Discussion	185
6.5 Conclusion	189
<u>CHAPTER 7 – SUMMARY AND CONCLUSION</u>	<u>190</u>
7.1 Aims	190
7.2 Summary of Findings	191

7.2.1 <i>Physical fitness testing as part of the TI process</i>	191
7.2.2 <i>Physical fitness testing as part of the TD process</i>	195
7.3 <i>Practical Implications</i>	196
7.4 <i>Directions for Future Research</i>	199
7.5 <i>Conclusion</i>	201
REFERENCES	203

I – ACKNOWLEDGEMENTS

I would like to express my gratitude to my academic supervisors: Firstly, **Dr. Angus Hunter**. Angus, despite your busy schedule, you always made time for me and made me feel like your door was always open. Thank you for continually educating me on becoming a good scientist and providing advice and guidance which has substantially improved the quality of my thesis. I look forward to continue to work with you in future and continuing to learn from you. Secondly, **Dr. Dajo Sanders**. Dajo, your academic and practical expertise has been absolutely pivotal in producing this thesis. You have been a great role model for me academically, as such a brilliant and successful scientist at such a young age. I will continue to strive to set my standards and ambitions for my research as high as you do for yours. Finally, **Dr. Calum Arthur**. Calum, although you have now moved on to an exciting role with UK Sport, I would like to thank you for your input and guidance during the first half of my PhD. I really appreciate your support and guidance, specifically encouraging my autonomy in shaping this thesis. I would also like to thank **Dr. Tony Myers** from Newman University for your expertise and guidance with the Bayesian analysis within Chapters 5 and 6 of this thesis, and, to **Mr. Chris Grigson** for his technical expertise in the development of the lower body reaction time test used within Chapter 4.

To my colleagues within the **Physiology, Exercise and Nutrition Research Group** here at the University of Stirling. I have truly enjoyed being a part of such a passionate and ambitious group of scientists and hope to continue to work with you all in future. Also, to fellow students who I have had the pleasure of sharing an office with during my PhD studies. **Christine, Ross, and Nina** – thank you for the companionship during the first half of my PhD, it helped a lot coming to the office every day knowing that you were all there. Secondly, the guys from 3B139. **Matt, Brian, and Jamie** – I've thoroughly enjoyed sharing an office (and lots of afternoon tea) with you all over the last 9 months.

To the **youth soccer players** across Scotland who participated in my studies, none of this would have been possible without your efforts and participation, thank you! Also, to the **coaches** and **academy staff** who participated and supported my studies. There are too many

of you to name individually, however, a special thanks is due to all at the **Forth Valley Football Academy**, in particular, **Michael McArdle** and **Jamie Swinney**.

Lastly, and most importantly, I would like to thank my family – the most important people in my life. First, my **Mum and Dad**. Your support and pride has been a constant source of motivation to me throughout my entire academic career. You have both been there for me, Jess, and Norah every step of the way over recent years – thank you for allowing me to pursue this goal. **Jess**, you have stood by me every step of the way and supported me endlessly. You are as much to credit for this thesis as I am, I truly couldn't have done this without you. I look forward to becoming your husband in the weeks to come. Little **Norah**, over the last three years you have provided me with focus and perspective to better myself personally and professionally. Whilst completing my PhD alongside starting a family was indeed challenging at times, coming home to you each day always put a smile on my face. Finally, a special mention to my late Grandfather - **Donald Howard**, who spoke so proudly of the thought of me receiving my Doctorate. Even during doubtful and difficult times, giving up was never an option.

II – PUBLICATIONS

The following publications arose directly from the work presented in this thesis:

Publications in peer-reviewed journals

Dugdale, J.H., Arthur, C.A., Sanders, D., & Hunter, A.M. (2019) Reliability and validity of field-based fitness tests in youth soccer players. *European Journal of Sport Science*, 19(6), 745-756.
<https://doi.org/10.1080/17461391.2018.1556739>

Conference proceedings

Dugdale, J.H., Arthur, C.A., Sanders, D., & Hunter, A.M. (2018) Reliability, Validity, and Sensitivity of Commonly Used Field-based Fitness Tests in Youth Soccer Players. *European College of Sports Science Congress*. Oral presentation. July. Dublin, IRE.

(Short-listed for European College of Sports Science Congress, Young Investigator Award)

III – GENERAL ABSTRACT

“Towards a Better Understanding of the Value of Physical Fitness Testing within the Identification and Development of Youth Soccer Players”

James H. Dugdale

The aim of this thesis is to better understand how physical fitness testing may be used to contribute towards talent identification (TI) processes of youth soccer players, and how valid physical fitness testing methods may be when implemented within talent development (TD) of various samples of youth soccer players. In the first study of this thesis (**Chapter 3**), discriminative ability of a comprehensive battery of commonly-used field-based fitness tests relating to change of direction (COD), sprinting, strength, and jumping performance was assessed, alongside examining reliability of all measures across a broad range of ages. Findings from this initial study suggest that a comprehensive fitness test battery can discriminate between distinct performance standards with reasonable accuracy; $\chi^2 (7) = 101.646$, $p < 0.01$, with 70.2% of players being correctly classified. However, may lack the ability to differentiate between more homogenous groups of youth soccer players. Moreover, this first study identified potential lower reliability of COD tests (ICC = 0.57-0.79; $p < 0.01$) in chronologically younger athletes. Building on the results of the first study, which demonstrated a lower reliability of COD tests in younger soccer players, the second study of this thesis (**Chapter 4**) assessed reliability of alternative COD tests, alongside reliability of an agility test, in an attempt to identify a reliable method of assessment for these characteristics across the entire age range within a youth soccer academy. In addition, relationships between associated physical/reactive qualities and agility performance were assessed. Measures examined within this study demonstrated improved and acceptable reliability comparative to that of the previous study (ICC = 0.82-0.91; CV = 1.5-2.0; d : 0.00-0.08), however, relationships between age ($r = -0.28 - r = -0.41$) and maturity status ($r = -0.39$) and between-trial performance differences were observed. Moreover, linear sprint and COD performance demonstrated large to very large relationships with agility performance ($r = 0.63-0.71$),

with reaction time demonstrating small to moderate relationships only ($r = 0.22 - 0.38$). These findings suggest that physical qualities relate strongly with agility performance within this sample, and that the COD and agility tests adopted within this study possess good between-day reliability, therefore providing meaningful and objective data for monitoring development of youth soccer players. The third experimental study within this thesis (**Chapter 5**) assessed accuracy between objective (fitness test performance) and subjective (coach rating for corresponding physical quality) measures of physical fitness characteristics relative to youth soccer performance. In addition, considering influence of multiple coaches and practitioners involved within decision making processes throughout youth academy soccer, agreement between lead and assistant coaches was assessed when rating identical players and abilities. Moderate-to-substantial relationships between inter-coach ratings were observed ($\omega = 0.48-0.68$), however, coach ratings were skewed in nature and only accurate in their ratings of highest and lowest performers. These findings suggest that the translation between objective and subjective assessment methods may be effective when attempting to differentiate between distinct population groups, however this method may lack sensitivity when evaluating homogeneous samples. The final study of this thesis (**Chapter 6**) investigated differences in age of recruitment, alongside longitudinal performance differences on field-based fitness tests of successful vs. unsuccessful graduates across an entire age spectrum recruited by a professional soccer academy. The majority (68%) of successful players were recruited to the academy at 12-years of age or older, and, successful academy graduates were only observed to physically outperform their “unsuccessful” counterparts from ~13-14 years of age onward, with either no differences in performance, or, performance on physical fitness tests favouring “unsuccessful” players prior to this age. These findings further support the notion that high achievers during childhood and early adolescence may not translate into successful senior professionals and raise question towards predictive and early specialisation models of TI. The studies presented in this thesis will considerably add to the body of research, effectively informing youth soccer practitioners, and enhancing practice around TI and TD.

IV – LIST OF FIGURES

- Figure 2.1** A multi-disciplinary model of potential predictors of talent in soccer (Williams & Reilly, 2000). **20**
- Figure 2.2** Scopes of talent identification and development (Sarmiento, Anguera, *et al.*, 2018). **23**
- Figure 3.1** Sample breakdown and participant descriptives for age groups, identification status, and playing standard. Age (years); Stature (cm); Body mass (kg). Data are presented as mean \pm SD. **96**
- Figure 3.2** Between-trial mean difference comparisons for COD tests across individual age groups. **A:** 505COD, **B:** T-Test. * indicates differences between U11/U12 and U13-U17 age groups; α indicates differences between U11-U13 and U14-U17 age groups ($p < 0.01$). **104**
- Figure 3.3** Z-score mean differences on performance tests between unidentified and identified player groups. **A:** Grip Strength, **B:** SBJ, **C:** CMJ, **D:** 505COD, **E:** T-Test, **F:** 10m Sprint, **G:** 20m Sprint. * indicates higher than unidentified ($p < 0.01$); α indicates higher than unidentified ($p < 0.05$). **106**
- Figure 3.4** Z-score mean differences on performance tests between different playing standards. **A:** Grip Strength, **B:** SBJ, **C:** CMJ, **D:** 505COD, **E:** T-Test, **F:** 10m Sprint, **G:** 20m Sprint. * indicates higher than amateur; α indicates higher than development; β indicates higher than performance ($p < 0.01$). δ indicates higher than amateur; γ indicates higher than development; Ω indicates higher than performance ($p < 0.05$). **107**
- Figure 4.1** Layout and set up of the Y-Sprint drill for both PRE and REACT conditions. **122**
1 = phase 1, 2 = phase 2, Total = total time.
- Figure 4.2** Layout and set up of the ‘complex’ version of the LBRTT (Spiteri, Cochrane, & Nimphius, 2013). **124**

Figure 4.3 Relationship between PRE and REACT conditions of the Y-Sprint drill: A – Y-Sprint(Total); B – Y-Sprint(1); C – Y-Sprint(2).	132
Figure 4.4 Relationships observed between fitness test variables and performance on: A – Y-SprintREACT(Total); B – Y-SprintREACT(1); C – Y-SprintREACT(2). Data are displayed as Pearsons r correlations \pm 95% confidence intervals.	133
Figure 5.1 A visual example of calculations applied for coach ratings 1 to 5 from the monotonic regression model.	150
Figure 5.2 Raw data boxplots for lead and assistant coach ratings for: A) Yo-Yo test distance; B) CMJ height; C) FMS score; D) maturity offset years; E) 5m sprint times; and F) 20m sprint times.	156
Figure 5.3 Marginal effects of the Bayesian monotonic ordinal regression models (\pm 95%CI) for lead and assistant coach ratings at population level for: A) Yo-Yo test distance; B) CMJ height; C) FMS score; D) maturity offset years; E) 5m sprint times; and F) 20m sprint times.	157
Figure 6.1 Bayesian logistic regression model of probability of obtaining a professional contract given a player's starting age in the academy. Data are displayed as estimates \pm 95%CI.	175
Figure 6.2 Interaction plots between age and success for: A) 5m sprint; B) 10m sprint; C) 20m sprint; D) CMJ; E) YYIRT L1; F) Height, and; G) Weight.	179

V – LIST OF TABLES

Table 2.1 Empirical evidence of the cross-sectional relevance of physiological and physical assessments to TI in youth soccer.	84
Table 2.2 Empirical evidence of the prognostic relevance of physiological and physical predictors to TI in youth soccer (adapted from Murr, Raabe & Höner, 2018).	85
Table 3.1 Between-day test-retest reliability of field-based fitness tests across age groups U11-U17.	103
Table 4.1 Anthropometric values and performance scores for all tests displayed by age group.	128
Table 4.2 Between-day test-retest reliability for COD and agility tests displayed by age group.	129
Table 4.3 Relationships between age/maturity offset and between-trial differences in performance for COD and agility tests.	130
Table 4.4 Relationships between fitness test variables and performance on the Y-SprintREACT(Total).	135
Table 5.1 An example output from a monotonic regression model predicting distance covered on the YYIRT L1 by coach rating at population level.	150
Table 5.2 Sklar’s ω for the level of agreement of the ratings between the lead coach and assistant coach.	151
Table 5.3 A Bayesian estimation of the coefficient of variation (R^2) with 95% credible intervals for each of the Bayesian monotonic ordinal regression models.	152
Table 5.4 Descriptive statistics of measured variables for coach’s ratings of players’ corresponding physical abilities.	154
Table 5.5 Coefficients, simplex parameters and 95% credible intervals for Bayesian monotonic ordinal regression models for performance measures predicted by the ratings of lead coach.	158

Table 5.6 Coefficients, simplex parameters and 95% credible intervals for Bayesian monotonic ordinal regression models for performance measures predicted by the ratings of assistant coach.	159
Table 6.1 Percentages of successful vs. unsuccessful players given their starting age.	174
Table 6.2 Descriptive statistics for 5/10/20m sprint, CMJ, YYIRT L1, stature, and mass for successful vs. unsuccessful players aged 10-17.	177
Table 6.3 Predictions and lower/upper 95%CI from the Bayesian regression model for differences in 5, 10, and 20 metre sprint times for successful vs. unsuccessful players.	178
Table 6.4 Predictions and lower/upper 95%CI from the Bayesian regression model for differences in YYIRT L1 and CMJ performance for successful vs. unsuccessful players.	183
Table 6.5 Predictions and lower/upper 95%CI from the Bayesian regression model for differences in stature and mass for successful vs. unsuccessful players.	184

VI – LIST OF ABBREVIATIONS

30-15 _{IFT}	-	30-15 intermittent fitness test
4G	-	4 th generation
505COD	-	505 change of direction test
ANOVA	-	Analysis of variance
APHV	-	Predicted age at peak height velocity
C	-	Celsius
CAS	-	Club Academy Scotland
cm	-	Centimeter
CMJ	-	Countermovement jump
COD	-	Change of direction
CV	-	Coefficient of variation
<i>d</i>	-	Cohen's <i>d</i> effect size
DXA	-	Dual-energy X-ray absorptiometry
FIFA	-	Fédération Internationale de Football Association
FMS	-	Functional movement screen™
g	-	Gram
GPS	-	Global positioning system
HHD	-	Hand-held dynamometry
ICC	-	Intraclass correlation coefficient
kg	-	Kilogram
km	-	Kilometre
LBRTT	-	Lower body reaction time test
LED	-	Light emitting diode
LOO	-	Leave-one-out
LTAD	-	Long-term athlete development
m	-	Metre
m505COD	-	Modified 505 change of direction test

min	-	Minute
mL	-	Millilitre
MRS	-	Maximal running speed
N	-	Newtons
NCAA	-	National Collegiate Athletic Association
PHV	-	Peak height velocity
<i>r</i>	-	Pearson's <i>r</i> correlation coefficient
RAE	-	Relative age effect
RFD	-	Rate of force development
RM	-	Repetition maximum
s	-	Second
SBJ	-	Standing broad jump
SD	-	Standard deviation
SFA	-	Scottish Football Association
SJ	-	Squat jump
SSG	-	Small-sided game
T-Test	-	T-Drill change of direction test
TD	-	Talent development
TE	-	Typical error
TI	-	Talent identification
UEFA	-	Union of European Football Associations
VO _{2max}	-	Maximal oxygen consumption
ω	-	Sklar's omega
Y-SprintPRE	-	Pre-planned version of the Y-Sprint drill
Y-SprintREACT	-	Reactive version of the Y-Sprint drill
YYIRT L1	-	Yo-Yo intermittent recovery test (level 1)
YYIRT L2	-	Yo-Yo intermittent recovery test (level 2)

CHAPTER 1

INTRODUCTION

1.1 Background

Soccer is the most popular sport in the world. A recent systematic review and meta-analysis indicated that soccer was second only to “walking” when considering physical activity modalities of children, adolescents, and adults globally (Hulteen *et al.*, 2017). Data from the Fédération Internationale de Football Association (FIFA) Big Count initiative in 2006 also report that, at the time, global soccer participation was reported at approximately 270 million people, more than any other sport. Whilst this initiative has not since been repeated, many anticipate this number to have further increased over the last decade following advancements in accessibility of facilities, and formal participation strategies by governing bodies (the Football Association, 2018). Across a similar timespan at the professional level, the European professional football market has almost doubled in size, reporting stepwise increases in yearly revenue from €13.6B in 2006/07 to €25.5B in 2016/17 (Statista, 2018b). These financial developments have transferred directly to the “coalface” and have influenced a meteoric increase within the soccer player transfer market, resulting in clubs paying more for players now than ever before. Soccer powerhouses such as Manchester City, Chelsea, Manchester United, and Paris Saint-Germain hold reputations for spending extortionate amounts to strengthen their squads, hand-picking the elite from around the globe with an almost limitless bank roll (Statista, 2018a). On the contrary, smaller clubs have benefitted from life changing sums of money from these super-clubs by selling their talented youngsters and home-grown heroes. By adopting appropriate and effective development methods, soccer clubs, at any interval of wealth, can benefit exponentially from buying or selling young

talent. Accordingly, identification and development of talented young soccer players is, now more than ever, at the forefront of any professional soccer club's strategy.

Whilst discussed congruently, definitions of talent identification (TI) and talent development (TD) differ within the literature. TI refers to the process of recognising current participants with the potential to become elite players (Williams & Reilly, 2000; Unnithan *et al.*, 2012). Conversely, TD is a complex and dynamic pathway construed by interactions of social, performance, and education factors (Burgess & Naughton, 2010). Methods of assessment and analysis for TI and TD of youth and adolescent athletes have developed substantially over recent years. Researchers and practitioners suggest this to be due to increases in scientific knowledge and prevalence of relevant applied research (Dodd & Newans, 2018; Figueiredo *et al.*, 2014), advancements in technology and data analytics (Huijgen *et al.*, 2014; Rabbani, Kargarfard, & Twist, 2018), and increases to the demands of professional soccer (Barnes *et al.*, 2014; Dodd & Newans, 2018; Murr, Raabe, & Höner, 2018). What previously existed as traditional scouting methods employed by clubs to observe training or game scenarios and identify promising young players through subjective "expert" opinion, has since become a complex and multi-disciplinary assessment process (Reeves, Roberts, *et al.*, 2018; Unnithan *et al.*, 2012). Whilst coach opinion and subjective input of technical and skills coaches continue to carry substantial weight within the selection/deselection process, the role of sport science staff offering additional services and expertise from the supplementary sciences within TI and TD has increased considerably (Unnithan *et al.*, 2012; Williams & Reilly, 2000; Wilson *et al.*, 2016).

"Sports science, without question, is the biggest and most important change in my lifetime."

Sir Alex Ferguson (2013)

Sport science has made its way to the forefront of practices implemented by professional football clubs during daily operations. Increased demands of modern day sport has resulted in a greater emphasis placed upon training, monitoring, and recovery processes in addition to skills and technical training (Malone *et al.*, 2015; Morgans *et al.*, 2014a; Thorpe *et al.*, 2016). Subsequently, modern day soccer players must engage with physical preparation (Turner & Stewart, 2014), nutrition (Devlin *et al.*, 2017), performance analysis (Memmert, Lemmink, & Sampaio, 2017), and psychology (Abdullah *et al.*, 2016) practices, amongst others, to remain healthy and competitive across densely populated seasons of association soccer. Perhaps the most notable development within competitive soccer in recent years is the increased physical demand of training and gameplay (Anderson *et al.*, 2016). Currently, players are covering greater distances, performing higher numbers of sprints and explosive movements, and reaching higher running velocities within games than in previous years (Barnes *et al.*, 2014). For example, across 7 seasons of English Premier League soccer, high-intensity running distance and actions increased by ~30% (890 ± 299 vs. 1151 ± 337 m, $p < 0.001$) and ~50% (118 ± 36 vs. 176 ± 46 , $p < 0.001$), respectively (Barnes *et al.*, 2014). Moreover, it has become increasingly common for soccer players to participate in numerous competitions across the season, resulting in densely populated fixture schedules (Morgans *et al.*, 2014b). As a result, increased physical fitness levels are required to achieve and sustain these competitive demands (Mujika, Santisteban *et al.*, 2009; Sporis *et al.*, 2009). Whilst competitive soccer is certainly much more than an athletic contest, the metaphoric bar for physical ability required to survive within the professional domain has been raised dramatically. Subsequently, these physical developments observed in senior professional soccer have influenced approaches administered at youth level, as coaches and practitioners attempt to prepare the next

generation of the elite (Dodd & Newans, 2018; Murr, Raabe, *et al.*, 2018; Rowat, Fenner, & Unnithan, 2017; Unnithan *et al.*, 2012).

In contempt of critique in years past, the benefits of early exposure to physical development prior to adulthood have since been acknowledged and prioritised across youth sports globally (Lloyd & Oliver, 2012). It is now commonplace for youth athletes to engage with a variety of physical preparation modalities as part of their sporting development. Moreover, physical competency and capacity of senior athletes has been associated with early exposure to physical development opportunities throughout childhood and adolescence (Gonaus & Müller, 2012; Haugaasen, Toering, & Jordet, 2014). However, the body of literature surrounding adolescent athletes has historically been scarce comparative to adults. The unique challenges and inconsistencies experienced throughout the adolescent development process have previously prevented translation of information between senior–youth samples regarding physical training and testing (Malina *et al.*, 2015; Pearson, Naughton, & Torode, 2006). Over recent years, substantial attempts have been made to better understand characteristics of child and adolescent athletes (Murr, Feichtinger *et al.*, 2018; Murr, Raabe, *et al.*, 2018). However, resultant of this imbalance in research investment, knowledge gaps still exist regarding the appropriateness of methods to assess and monitor youth athletes throughout their developmental years.

As already suggested, the multi-faceted nature of competitive soccer requires a multi-disciplinary approach to TI and TD to ensure effective and non-biased selection of talented youngsters (Burgess & Naughton, 2010; Reilly *et al.*, 2000; Vaeyens *et al.*, 2006). Despite this, physical and physiological attributes have arguably received the greatest attention within relevant literature in adolescents, with testing and monitoring of generic physical abilities

being embedded as staple methods during the identification and development of youth soccer players (Dodd & Newans, 2018; Murr, Raabe, *et al.*, 2018). Researchers relate this prevalence to recent developments in physical demands of senior soccer, briefly discussed above, and the perceived importance of physical attributes within the TI and TD process reported amongst coaches (Issurin, 2017; le Gall *et al.*, 2010). More recently, however, the prognostic value and validity of these commonly used fitness tests and testing batteries within adolescents has been questioned (Murr, Raabe, *et al.*, 2018; Sarmiento, Anguera, *et al.*, 2018). What remains somewhat unclear is how physical and physiological testing methods fit within the larger picture of TI and TD, and how employing these methods relate to alternative selection/deselection processes, and long-term success. Similarly, it has been conclusively proven that child and youth athletes possess vastly different physiology and abilities than their mature and senior counterparts (Matos & Winsley, 2007; Pearson *et al.*, 2006). Yet, prescription and implementation of methods to evaluate physical ability and capacities of youth and child athletes often rely upon validation achieved in senior athletes (Vaeyens *et al.*, 2008). Henceforth, it has become apparent that further research is required to further inform researchers and practitioners on knowledge gaps that remain regarding the use of physical fitness testing methods, both as appropriate measures to assess this population, and as a component of the TI process.

1.2 General aim of this thesis

The overall aim of this thesis is to better understand how physical fitness testing may be used to contribute towards the TI process of youth soccer players, and how valid physical fitness testing methods may be when implemented within TD of various samples of youth

soccer players. Whilst physical fitness testing remains a single contributing component of a complex and multi-disciplinary process to assess and identify talented young soccer players, developing a better understanding of the physical fitness testing process would assist with the interpretation and weighting placed upon findings by practitioners, contributing towards a more representative assessment process of youth soccer players.

1.3 Overview of thesis

This introduction chapter is followed by a review of literature aiming to provide a description and critical evaluation of current evidence available on the TI and TD process of youth soccer players, the physical demands of competitive soccer, and methods of performance evaluation employed within soccer. The underpinning emphasis of this literature review is to discuss the physical and physiological considerations when assessing adolescent (age 10-19) and pre-adolescent (age 9-14) athletes. The literature review aims to provide an overview of the appropriate literature relevant to the research questions and aims of this thesis, highlight avenues for research that will inform current practice within this population group, and state the specific aims of this thesis. Four empirical chapters will follow aiming to further develop and inform practitioner knowledge and understanding of this topic. Each study within these chapters will address individual study aims and research questions relative to the overall thesis aims, and will include separate introduction, methods, results, discussion, and conclusion sections. Following the four empirical chapters that form the core of this thesis, a final summary and conclusion chapter is presented that draws together all of the findings from the studies and discusses their advancement of the current bed of literature.

CHAPTER 2

REVIEW OF LITERATURE

As illustrated in the previous chapter, appropriate identification and development of youth soccer players is an integral component of modern-day soccer academies. Given physical progressions of modern-day soccer, and attention given to physical attributes during selection/deselection and recruitment of promising young soccer players, a comprehensive knowledge of commonly-used procedures and tests is critical for decision making. In light of the aforementioned purpose of this thesis, this review of literature will present and critically evaluate research on the use of physical fitness testing within TI and TD processes, specifically for youth soccer players. In order to provide a more comprehensive overview, particularly around TI and TD methods in sport, some research in other sports will be drawn upon. To inform this review of literature, a PubMed search of relevant academic literature was performed. Terms such as: ‘talent identification’, ‘talent development’, ‘fitness testing’, ‘performance testing’, ‘selection/deselection’, ‘youth athlete’, ‘physical fitness’, ‘adolescent athlete’, ‘team sport’, ‘football’, ‘soccer’ were used. Additional research was sourced via reference lists from associated papers and recommended reading from ‘Mendeley’ and ‘ResearchGate’ platforms. In this literature review, qualitative interpretations of standardised effect sizes and correlation coefficients reported in different studies will be described as per Hopkins et al., (2009). Qualitative interpretation of effect sizes (Cohen’s *d*): 0–0.19 trivial; 0.20–0.59 small; 0.60–1.19 moderate; 1.20–1.99 large; ≥ 2.00 very large. Interpretation of the strength of correlation coefficients (Pearson’s *r*): 0–0.09 trivial; 0.10–0.29 small; 0.3–0.49 moderate; 0.50–0.69 strong; 0.70–0.89 very strong; 0.90–0.99 nearly perfect; 1.00 perfect.

2.1 Talent identification

TI may be defined as processes for identifying young athletes who possess potential to become successful senior professionals (Johnston *et al.*, 2018). Whilst desire and ambition to identify and recruit talented young athletes has likely always been a part of sport, structured TI processes have been documented for several decades, originating in the 1970's within track and field sports (Gimbel, 1976 in Regnier, Salmela, & Russell, 1993). Over time it became apparent that in order to optimally perform, different sports favoured specific physical abilities and somatotypes. Nowadays, it is easy to identify stereotypical sprinters, shot putters, or marathon runners, resultant of a greater understanding about base characteristics required for specific sports. Over the years, coaches identified key performance indicators relative to competitive success within particular disciplines and began to integrate baseline assessments of these variables within the recruitment process. This approach rapidly gained popularity and was adopted across various sports over years to come (Abbott & Collins, 2002). However, despite good intentions, transferability of these processes, particularly within team sports, proved to be difficult.

2.1.1 Talent identification in soccer

Unlike more unidimensional sports whereby TI processes originated, researchers and practitioners soon acknowledged diverse and multifarious identities of "successful" team sport professionals, and, varying demands of positional differences (Hoare & Warr, 2000; Reilly *et al.*, 2000; Williams & Reilly, 2000). Moreover, whilst inaugural work by Gimbel (1976) approached TI from three cross-discipline perspectives: 1) trainability; 2) motivational aspects, and; 3) morphological and physical considerations, suitability of adopting this approach within team sports, again, faced scrutiny. Team sport coaches stressed the

importance of technical and tactical qualities relative to competitive success, favouring traditional scouting methods adopted historically during TI. Historically, TI in soccer relied on coach subjective opinion on ability or “talent” of a young player (Unnithan *et al.*, 2012; Williams & Reilly, 2000). Coaches or scouts would observe a competitive game or training session and rate players subjectively on skills and abilities demonstrated. This process was often influenced by subconscious or personal bias and opinion held by the coach, or club philosophies on qualities “good” or “successful” players should possess. The flaws of adopting this process in isolation was soon identified by researchers, with calls for a more informed and scientific approach to TI (Williams & Reilly, 2000). Seminal work by Williams & Reilly (2000) lead the way in discussing the multi-faceted nature of “talent”, proposing a multi-disciplinary model when implementing TI processes within soccer (**Figure 2.1**).

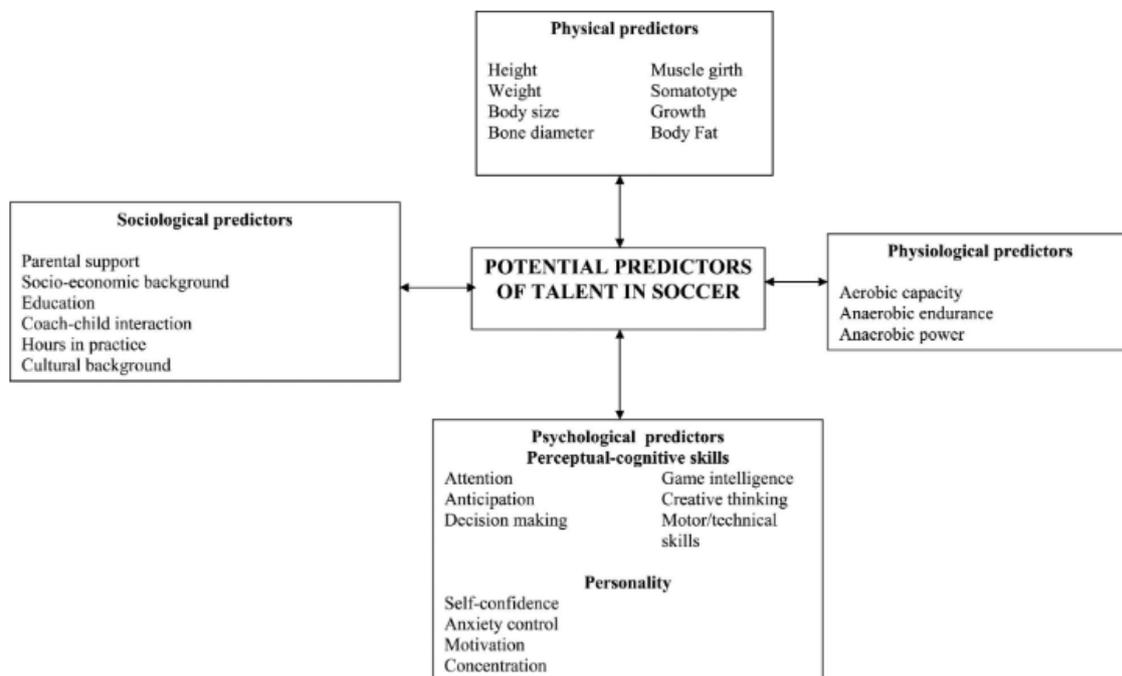


Figure 2.1 A multi-disciplinary model of potential predictors of talent in soccer (Williams & Reilly, 2000).

This early work from Williams & Reilly (2000) was amongst the first suggesting the range of potential predictors of talent in soccer, sparking a revolution in the approaches adopted within the soccer TI process. Over subsequent years, researchers attempted to adopt a multi-disciplinary approach to TI as proposed by Williams & Reilly (2000).

Work by Vaeyens *et al.* (2006) further progressed TI literature by implementing one of the first longitudinal and multi-disciplinary models applied in youth soccer, the “Ghent Youth Soccer project”. During this project, the authors monitored a range of physical and physiological capacities alongside technical skills performance in a cross-sectional, mixed-longitudinal sample across 5 years. Findings of the study indicated the ability to discriminate between performance standards, however, noted vast changes in importance of variables observed across age groups. Whilst the impressive sample ($n = 232$) and data set (17 variables at 5 time points) attained by Vaeyens *et al.* (2006) progressed current knowledge of soccer TI at the time, the authors acknowledged limitations of their findings relative to ability to correctly “identify talent”. The cross-sectional nature of the study, alongside the absence of perceptual-cognitive, tactical, or psychological variables important to successful soccer performance proposed the need for further research within the TI domain.

Soon thereafter, the same group published a review article discussing some of the proposed limitations within the “Ghent Youth Soccer project” (Vaeyens *et al.*, 2008). The review discussed the validity of TI models, posing the suggestion that many are unidimensional and exclusionary in nature. Moreover, they reiterate the flaws concerning assumptions placed upon findings from cross-sectional study designs, challenging the translation of high performance from adolescence–adulthood, and again proposing a longitudinal approach to TI. The opinions of Vaeyens *et al.* (2008), similar to those initially proposed by Williams &

Reilly (2000), were echoed by many researchers over subsequent years (Burgess & Naughton, 2010; Meylan *et al.*, 2010; Unnithan *et al.*, 2012). Yet, limited progress was made in practically implementing multi-disciplinary and longitudinal study designs as intended. Despite this proposal from Williams & Reilly (2000) almost two decades ago, few studies have made significant progress in advancing the body of literature with multi-discipline (Forsman *et al.*, 2016; Huijgen *et al.*, 2014; Reilly *et al.*, 2000) or longitudinal (Deprez, Buchheit *et al.*, 2015; Leyhr *et al.*, 2018; Saward *et al.*, 2016) data sets.

These views are summarised within a recent systematic review by Sarmiento, Anguera, *et al.*, (2018) providing an update on the original model by Williams & Reilly (2000), highlighting the complex and multidimensional relationship between factors relative to talent in soccer (**Figure 2.2**), need for additional longitudinal studies within literature, and limited number of samples containing elite or professional youth soccer players. However, considerable advancement has been made within-disciplines to better understand methodological issues and confounding variables within established protocols and procedures, alongside development of new methods providing more meaningful and representative data. For example, within each contributing sub-discipline (eg. physiology, psychology, skill, etc.), there has been development in ability to assess parameters, with further information regarding valid and representative means of assessment coming to light. However, despite this increase in discipline-specific knowledge, it is the unison of these abilities that is truly dictates and informs TI, of which is lacking within the current literature.

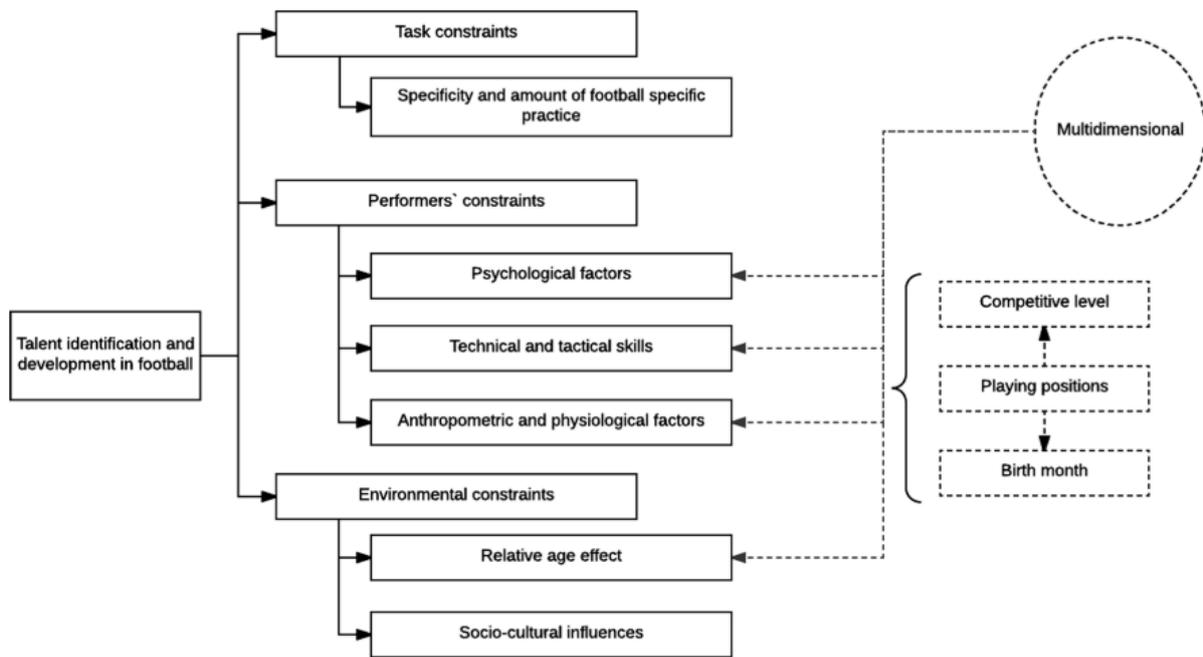


Figure 2.2 Scopes of talent identification and development (Sarmiento, Anguera, *et al.*, 2018).

2.1.2 Talent development

Exclusive and results-driven approaches to TI systems has resulted in significant negative publicity in recent years (Güllich, 2014; Rongen *et al.*, 2018). Given that TI systems are predominantly focussed upon identifying adolescent athletes, the “healthiness” of these processes is questioned (Ford *et al.*, 2011; Malina, 2010; Rongen *et al.*, 2018). Moreover, TI processes have faced scepticism of their effectiveness in producing senior talent as intended (Vaeyens *et al.*, 2009; Vaeyens *et al.*, 2008). Considering these potential limitations of TI, a shift towards an approach focussing on TD is proposed by some researchers (Coutinho, Mesquita, & Fonseca, 2016; Williams & Reilly, 2000). Confusingly, TI and TD are often used interchangeably within the literature. However, TD commonly identifies as the progression of various abilities relevant to success through practice and training (Coutinho *et al.*, 2016),

opposed to the endeavour to objectify ability observed during TI processes. Similarly, as mentioned, many believe that it is not possible to predict talent, therefore an approach prioritised around TD remains the only plausible option when considering the development of youth athletes (Johnston *et al.*, 2018; Vaeyens *et al.*, 2008). The nature of TD asserts the need to inform coaches and practitioners of developments experienced throughout training and development processes (Christensen, 2009). TD processes are predominantly inclusive and multi-disciplinary in nature, often adopting an approach centralised upon developing weaker or limiting attributes (Vaeyens *et al.*, 2008). What segregates TD from traditional coaching processes by nature, is its impartial and objective approach. Appropriate TD approaches are established upon objective and data-driven methods, void of subjective input and bias, with appropriate development strategies being issued based upon the outcomes (Ford *et al.*, 2011; Pearson *et al.*, 2006). For example, Deprez, Valente-Dos-Santos, *et al.* (2015) conducted a longitudinal study on 555 male youth soccer players from 2 professional Belgian soccer clubs. The authors monitored both countermovement jump (CMJ) and standing broad jump (SBJ) performance from age 7 (the youngest age of entry to the academies) until age 20 (the latest age players were retained at the academy before progressing to the first team or being released). Main findings including a predictive regression model between measured and predicted performance from childhood to adulthood (across adolescence), allowing for better understanding of progression rates experienced by this group throughout their physical and biological development. Findings such as this better inform an ability to make appropriate decisions and manipulations to training and development activities. Whilst the principles behind TD are well intended, several limitations and considerations of this method, alongside concerns regarding TI, are raised.

2.1.3 Limitations of talent identification

Ability to correctly identify talented young athletes is an attractive premise to coaches when considering future financial and competitive success at senior level (Abbott *et al.*, 2005; Vaeyens *et al.*, 2008). However, identifying appropriate and effective methods to do so, has proven difficult due to the complex and multi-faceted construct of team sport competition (Reilly *et al.*, 2000; Williams & Reilly, 2000). TI has received significant research attention over the last decade. Yet, coach subjective influence continues to play a substantial role during TI processes (Larkin & O'Connor, 2017). Given advancements in technology and resources more readily available to coaches and practitioners, it was assumed that our ability to identify and predict talent would also progress. However, developments within TI literature prove quite the contrary; recent research further magnifies the complexity associated with TI processes across childhood and adolescence, alongside developing a better understanding of potential limiting factors prevalent within traditional TI methods (Larkin & Reeves, 2018; Reeves, Roberts, *et al.*, 2018). Similarly, the difficulty in collecting multi-disciplinary data accurately and consistently in a longitudinal fashion (as proposed within the literature) is noted by many researchers (Johnston *et al.*, 2018). This isn't to say there is no value in collecting monodisciplinary data. In fact, development within-disciplines over recent years has progressed ability to better interpret data and make more informed decisions during TI processes (Sarmiento, Anguera, *et al.*, 2018). However, this recent research has also demonstrated several considerations to be acknowledged within TI and TD, such as relative age effects, varied rates of growth and maturation experienced by adolescent athletes, and additional challenges regarding the efficacy of TI and TD processes.

2.1.3.1 *The relative age effect*

Given the importance of appropriate training and specific practices for developing expertise within given sports (Huijgen *et al.*, 2009; Leite, Baker, & Sampaio, 2009; Zibung & Conzelmann, 2013), early recruitment of individuals is an important consideration for successful TI. Consequently, in order to potentially maximise future potential, recruiters are attempting to identify talented youngsters during the formative years (5–13 years) (Hendry & Hodges, 2018). Due to the long withstanding categorisation based upon chronological age present in youth sport, it has been proposed that bias occurs favouring those born closer in proximity to the upper boundary of each age group (Helsen, Van Winckel, & Williams, 2005; Vaeyens, Philippaerts, & Malina, 2005), commonly referred to in the literature as the relative age effect (RAE). The RAE bias has been reported to influence selection/deselection processes (Del Campo *et al.*, 2010; Helsen *et al.*, 2005; Rubajczyk & Rokita, 2018), positional allocation (Towlson *et al.*, 2017), and performance on skills and physical measures (Lovell *et al.*, 2015; Votteler & Höner, 2014). Moreover, despite this evident bias at youth level, benefits translated to senior success are limited (Brustio *et al.*, 2018; González-Víllora, Pastor-Vicedo, & Cordente, 2015). Significance of RAE, however, remains inconclusive, with suggestions that its prevalence doesn't affect match outcome and season record (Kirkendall, 2014), or physical characteristics (Figueiredo *et al.*, 2018) of youth soccer players. In fact, researchers suggest that RAE is prevalent due to progressed rates of maturation, and an earlier entrance into puberty associated with chronologically older soccer players (Müller *et al.*, 2018).

2.1.3.2 *Maturation-selection phenomenon*

Anthropometric differences (height and mass) of players, particularly in the younger age groups, have been identified as playing an important role in performance and selection with physically bigger

players chosen over the smaller players (Johnson, Farooq, & Whiteley, 2017). Having a birth date immediately after the classification cut-off for age-based junior sport provides a developmental advantage over those born immediately before this date up to one year. These RAE advantages (**discussed in Section 2.1.3.1**) in development are seen to be enough to improve selection likelihood for youth athletes which carry through to adult-level elite sport where such early age-related advantages in development will have disappeared (Helsen *et al.*, 2005; Hirose, 2009; Vaeyens *et al.*, 2005). This has been termed the “initial performance effect” (Helsen *et al.*, 2005; Jimenez & Pain, 2008), and providing such an advantage to those lucky enough to have been born at the right time may be excluding others from exposure to training who may have sufficient skill, yet lack the physical development of their more mature colleagues. Indeed, studies from both French and Spanish football suggest that the RAE is a contributor to drop out rates in junior, but not adult football (where relative age effects of physical maturation will no longer exist) (Delorme, Boiché, & Raspaud, 2010; Jimenez & Pain, 2008). At the highest level, boys who have been lost to the football academy system are unlikely to be later identified as potential senior players in the professional ranks (Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009).

2.1.3.3 Growth and maturation

Harmonious with evident RAE in youth sport, biases towards advanced maturity status and early rates of growth also exist within TI systems. During childhood and adolescence, differences in maturity can be extensive. Amongst individuals of identical chronological age, advanced maturity can positively influence short term psychological (Holt & Dunn, 2004), physiological (Meylan *et al.*, 2010; Vandendriessche *et al.*, 2012), and sport-specific (Rommers *et al.*, 2018; Seward *et al.*, 2018) characteristics associated with improved soccer performance. Given the results-driven culture associated with soccer, a “winning mentality” exists amongst the philosophies of many clubs and coaches. As a result, strategies encouraging short-term success, opposed to long-term development, are often employed

within youth soccer academies (Burgess & Naughton, 2010; Reilly *et al.*, 2000; Unnithan *et al.*, 2012). It is this culture and approach that has established issues such as maturity bias and RAE, due to short-term advantages associated with having older, more mature players within teams. Despite providing potential advantages at youth level, the presumption that these superior abilities are retained throughout maturation and into adulthood, is incorrectly assumed (Ford & Williams, 2012). Moreover, rates of maturation across adolescence is non-linear in nature, and varies between individuals (Malina *et al.*, 2015). Nonetheless, likelihoods of initial recruitment, and progressing within professional soccer academies has been suggested to be influenced by maturity status (Johnson *et al.*, 2017; Malina *et al.*, 2015). Whilst it remains unclear whether advanced maturity status impacts current and long-term specific soccer performances (Borges *et al.*, 2018; Deprez, Buchheit, *et al.*, 2015; Malina *et al.*, 2005; Rowat *et al.*, 2017), physical maturation has historically, and continues to, influence TI processes.

2.1.3.4 Challenges of talent identification

As previously discussed, ability to correctly identify talented young players is an attractive premise. Despite a wealth of investment into TI literature over recent years, appropriateness (Abbott *et al.*, 2005), accuracy (Woods, Joyce, & Robertson, 2016), and ethics (Rongen *et al.*, 2018) of TI methods has also been equally challenged. Whilst the unstable and non-linear rate of maturation and development of adolescents, discussed above (**Section 2.1.3.3**), contributes to this debate, researchers pose several additional considerations questioning the validity of TI processes. Due to the lack of multi-disciplinary and longitudinal research available, limited evidence exists regarding importance or weighting of various contributors in relation to successful youth–senior transition or “success” (Ford *et al.*, 2012; Phillips *et al.*

2010). Therefore, coaches and practitioners remain unable to gain true understandings and interpretation of variables of interest providing meaningful influence on intended TI outcomes.

Practitioners have attempted to identify key components associated with improved soccer performances. However, it remains unclear how these variables influence competitive match play, or coach perception and rating (Güllich, 2014; Larkin & O'Connor, 2017; Unnithan *et al.*, 2012). Inevitably, despite attempts by researchers and practitioners to improve accuracy and appropriateness of TI processes, these processes must align with a demonstrable difference in performance, or positively inform the coach or decision-makers responsible during selection/deselection processes. However, few attempts to assess relations between objective and subjective judgements exist. Given the open and multi-faceted nature of competitive team sports, compartmentalisation of attributes and abilities observed within many TI processes receives scrutiny (Sarmiento, Anguera, *et al.*, 2018). Due to complex interactions of interdisciplinary issues directly impacting upon athletic opportunities and progression, it is intended that TI models consider incorporating multi-dimensional, represented tasks (Ford *et al.*, 2011). Some developments in validating methods, such as small-sided games (SSG) allowing simultaneous evaluations of several components contributing to soccer performance, have occurred in recent years (Almeida *et al.*, 2016; Fenner, Iga, & Unnithan, 2016; Unnithan *et al.*, 2012). Yet, whilst allowing for better interpretation of complex relationships between technical, tactical, and physiological interactions specific to soccer gameplay, abilities of single methods or processes to capture the breadth of potential predictors relative to successful TI in soccer, remains insurmountable (Sarmiento, Clemente, *et al.*, 2018).

Complexities of “talent” are often proposed as additional restrictions to implementing appropriate and successful TI methods (Abbott *et al.*, 2005; Abbott & Collins, 2004). Many suggest that due to this complexity, talent may never be construed, thus, making ability of conducting controlled methods and processes attempting to “measure” talent, defective in nature (Vaeyens *et al.*, 2008). Moreover, suggestions for improved TI processes are mostly descriptive, theoretical, and schematic in nature, remaining untested and offering limited application for coaches and practitioners to implement (Abbott & Collins, 2004; Reilly *et al.*, 2000; Vaeyens *et al.*, 2008). Thus, no globally accepted methods or models for TI exist within sport, and, many propose a shift to focus on TD when considering the preparation of promising young athletes (Abbott *et al.*, 2005; Baker, Schorer, & Wattie, 2018; Burgess & Naughton, 2010).

2.1.4 Limitations of talent development

Despite proposing more holistic and inclusive approaches to athlete development, some researchers share equal concerns around TD approaches as they do for TI. Effective TD depends upon athletes selected through TI, therefore posing similar ethical concerns regarding the initial selection/deselection process (Pankhurst & Collins, 2013). As introduced, a wealth of previous literature address TI and TD interchangeably, making interpretation of research propositions challenging and confusing, demonstrating the adjacency of these processes. Due to the heterogeneous nature of club philosophies across institutions, adopted development strategies can vary substantially (Martindale, Collins, & Abraham, 2007; Vaeyens *et al.*, 2006; Williams & Reilly, 2000). This is problematic, as multitudes of TD approaches provide limited meaningful longitudinal data. When considering purely a TD approach, cross-sectional methods can provide appropriate information to inform training

programmes and development plans. However, as previously suggested, these types of cross-sectional study designs provide limited information relevant to TI.

To ensure TD is prescriptive and unbiased, appropriate methods to gather data and inform decision making processes should be adopted (Wilson *et al.*, 2016). Therefore, abilities of these methods to provide valid, reliable, and sensitive information, appropriate to sporting performance, is crucial for representative TD processes. Considering the suggestion made earlier regarding the historic imbalance of attention within scientific literature between youth–senior athletes, there are inevitably “gaps” within current knowledge regarding this avenue of study. Previously, due to TI and TD purposes for producing successful senior professionals, much guidance and information provided to youth athletes was translated or adopted from adult practices (Pankhurst & Collins, 2013). As briefly addressed, many challenges exist concerning evaluations for developing and maturing youth athletes. Accordingly, quality of these measures to evaluate these complex samples of children and adolescents need to be comprehensively understood prior to implementation.

2.1.5 Talent identification – summary

- TI within diverse and multi-faceted team sports, such as soccer, appear substantially more complex than unidimensional sports.
- Whilst the desire to correctly identify and appropriately develop young athletes into successful senior professionals is apparent, ability to do so seems limited by both complexity of the issue, and an absence of appropriate information to inform decision making.
- Agreement between adopted TI and TD methods and coach perception remain inconclusive, with few attempts to further this research.

- An absence of multi-dimensional and longitudinal samples may limit usefulness and application of TI methods.
- Whilst TD approaches may appear more efficacious and ethical when considering developing youth athletes, limitations to this approach must also be acknowledged.
- The ever-growing knowledge base within this avenue of research is expanding, providing further clarity around individual disciplines, existing methods, and validating new methods – all contributing to a more educated TI process.
- Many complexities and considerations (such as the RAE and rates of growth and maturation) exist amidst the TI process – these should be acknowledged.

2.2 Physical characteristics of soccer

As ultimate aims of TI and TD are to appropriately identify and prepare youth players for a professional senior career, from a physical perspective, appropriate origins for this section of the literature review is to gain a thorough understanding of the physical demands of senior soccer. In order to effectively examine, monitor, and prescribe physical characteristics relevant to successful soccer performance, knowledge of the physical demands of training and competition must be understood. Whilst soccer remains a multi-faceted and multi-dimensional sport, the physical demands experienced during training and competition are amongst the most considered during the preparation process. Competitive soccer exhibits a range of demands onto its players. Not only must soccer players possess exceptional technical skill (Keller *et al.*, 2016), unrivalled tactical knowledge (Kannekens, Elferink-Gemser, & Visscher, 2011; Ward & Williams, 2003), and a wealth of psychological traits (Höner & Feichtinger, 2016) to succeed, but also diverse sets of physical abilities (Sporis *et al.*, 2009), allowing them to overcome the multitude of physical challenges and scenarios experienced on a day-to-day basis during training and competition. Although physical performances are not directly associated with success, they impact upon technical proficiency (Impellizzeri *et al.*, 2008; Rampinini *et al.*, 2008). Moreover, modern day soccer seasons require players to endure densely populated fixture schedules, demanding exceptional levels of physical conditioning (Anderson *et al.*, 2016; Morgans *et al.*, 2014a). Acknowledgement of these recent developments has resulted in further attention to training and monitoring in soccer from a physical perspective, and, an increase in responsibility placed upon the sport science support team during preparatory phases (Morgans *et al.*, 2014b).

2.2.1 Physical characteristics of professional soccer

A wealth of physical abilities have been associated with improved soccer performances (Stølen *et al.*, 2005). Additionally, it is proposed that players must be able to endure vast physical demands of soccer training and competition to survive at professional levels (Rampinini *et al.*, 2007; Sporis *et al.*, 2009). Therefore, underpinning physical abilities must be held by players to succeed as senior professionals. Physical performance has also been reported to differentiate between elite and non-elite senior soccer players (Ostojic, 2000; Sporis *et al.*, 2009). However, due to the multi-dimensional nature of competitive soccer gameplay, specifically, differences in demands between varied player positions, discrepancies exist regarding correct weighting and prevalence of various physical abilities relevant to success (Strudwick, Reilly, & Doran, 2002). Historically, endurance running performance has been advocated as a key physical attribute for professional soccer players, and, as a result, received considerable attention during the physical preparation of senior soccer players (Bangsbo, Mohr, & Krustup, 2006; Mujika, Santisteban, *et al.*, 2009). In recent years, however, prevalence of high intensity activity during game play has increased substantially, with limited increases in total distance covered (Barnes *et al.*, 2014). Moreover, associations have been reported between high intensity activities and subsequent positive match outcomes (Bush *et al.*, 2015; Di Salvo *et al.*, 2010). These recent developments have resulted in more attention being placed on the importance of high intensity activity within match play, and, accordingly, an increase in the value placed upon physical characteristics associated with these actions (Anderson *et al.*, 2016; Barnes *et al.*, 2014; Bush *et al.*, 2015). Therefore, both the historical physical demands of competitive professional soccer, and recent developments in physical demands of game play, must be considered when considering TI and TD of the next generation of soccer players.

2.2.1.1 Running characteristics of professional soccer

Soccer match play is characterised by brief bouts of high-intensity linear and multidirectional activity interspersed with longer, and variable recovery periods (Ingebrigtsen *et al.*, 2015). During a 90-minute game, elite-level senior players (excluding goalkeepers) cover ~10-12 km of total distance adopting various running modalities. Commonly, activities observed within a soccer match have been categorised as: standing (0–0.6 km·h⁻¹), walking (0.7–7.1 km·h⁻¹), jogging (7.2–14.3 km·h⁻¹), running (14.4–19.7 km·h⁻¹), high-speed running (19.8–25.1 km·h⁻¹), and sprinting (>25.1 km·h⁻¹) (Castagna *et al.* 2017; Stølen *et al.*, 2005). Whilst distances covered during competition have been reported to vary substantially based upon playing position and formation, it is suggested that pitch dimensions and transitions in possession impose minimum requirements of ~10 km during competition (Bradley *et al.*, 2011). To prepare players for these demands, senior soccer players have been reported to cover ~4-5 km within individual training sessions (Scott *et al.*, 2013), and ~800 km across a competitive season (Anderson *et al.*, 2016). Resultant of these requirements from training and match play, elite male out-field soccer players possess a $\text{VO}_{2\text{max}}$ of between 50–75 mL·kg·min⁻¹ (Stølen *et al.*, 2005).

Despite a distinct demand to cover substantial distances across training and competition, recent developments have seen increases in high-intensity and sprint activity as opposed to increases in total distance observed during senior soccer competition (Barnes *et al.*, 2014; Bush *et al.*, 2015). High-intensity activity within soccer can constitute a range of exercise modalities including high-speed running, sprinting, accelerating, and decelerating (Abt & Lovell, 2009). According to Bradley *et al.* (2011), the prevalence of high-intensity activities may vary dependent on playing position and style, however, have been reported to occur on

~120 occasions, on average, within a competitive match. Castagna *et al.* (2017) report that of the ~10–11 km total distance observed during competitive matches within their study, ~1.5–2.0 km was performed at high-intensity. A limitation when interpreting these data, however, is that various thresholds for categorisation of what constitutes as high- and very high-intensity running exist within the literature, leading to varied results (Abt & Lovell, 2009; Di Salvo *et al.*, 2010). Regardless, the presence of high-intensity activity within senior soccer match play is undeniable.

High-intensity running activity is an important contributor to positive match outcomes (Bush *et al.*, 2015; Di Salvo *et al.*, 2010; Faude, Koch, & Meyer, 2012). Faude *et al.* (2012) state that straight line sprinting is the most dominant action preceding goal scoring. Similarly, Di Salvo *et al.* (2009) found that goals conceded were also commonly preceded by high-intensity actions by a defending team of Premier League soccer players. During competitive Premier League match play, ~25–35 sprints ($>25.1 \text{ km}\cdot\text{h}^{-1}$) have been observed to occur, covering a combined distance of ~180–250 m (Di Salvo *et al.*, 2009). Again, this has been reported to be position specific, with wide midfielders and attackers performing greater numbers of sprints for a greater combined distance (Bradley *et al.*, 2011; Di Salvo *et al.*, 2009). Sprint distances of 5–30 m are commonly reported during competitive soccer, with almost 50% of observed sprints performed $<10 \text{ m}$ (Stølen *et al.*, 2005). The repeated nature of sprint activity within competitive soccer results in high frequencies of accelerations and decelerations. Accelerations and decelerations have been suggested to occur greater energy cost than constant speed movements (Osgnach *et al.*, 2010), and, due to occurring at low relative speeds, are commonly neglected when observing high-speed metrics (Akenhead *et al.*, 2013; Gaudino *et al.*, 2013). Around 150–200 accelerations, and 150–200 decelerations of varied intensity have been reported during elite match play (Akenhead *et al.*, 2013; Ingebrigtsen *et*

al., 2015). The multi-directional demands and varying nature of competitive soccer movements are, in large, responsible for these acceleration and decelerations. Resultant of the requirement to repeatedly perform the high-intensity movements, discussed above, underlying strength and power characteristics also hold perceived importance relative to soccer performance. Consequently, presence of the aforementioned activities have resulted in increased metabolic demands of soccer performance. Accordingly, these variables have received increased attention during the training process when preparing senior soccer players for the physical demands of competition.

2.2.1.2 Strength and power characteristics of professional soccer

Due to the multi-dimensional nature of competitive soccer, strength and power characteristics have always been present within the demands of game play. Muscular strength has been defined as the ability to exert force on an external object or resistance (Suchomel, Nimphius, & Stone, 2016). Similarly, muscular power can be defined as the amount of work produced per unit time, or the product of force and velocity (Cronin & Sleivert, 2005). Muscular power has been reported to be heavily dependent on maximal strength (Morrissey, Harman, & Johnson, 1995), with an increase in the latter being connected with an improvement in relative strength and therefore an improvement in power abilities. Whilst separate abilities, higher absolute performance is associated with performance at sub-maximal intensities, therefore increases in absolute strength/power characteristics may benefit sub-maximal performances in-game performances associated with strength/power qualities (Suchomel *et al.*, 2016). As stated, competitive soccer is an intermittent game requiring repeated performance of varied physical skills and abilities. Whereas attention to running demands has previously monopolised training priorities when

preparing athletes for soccer competition, an increase in prevalence of high-intensity activity observed within game play has influenced training processes in recent years. Consequently, development of specific strength and power qualities both in isolation (Turner & Stewart, 2014), and manipulated through sport-specific training scenarios (Morgans *et al.*, 2014a), is a routine part of a competitive soccer players training schedule.

Improved strength and power qualities have been comprehensively associated with increases in speed and force of movement, allowing individuals to jump higher, sprint faster, and change direction more efficiently (Suchomel *et al.*, 2016). The most decisive situations within a competitive soccer match are compounded by strength, power, and speed performance such as linear sprint, change of direction (COD), and jump actions (Faude *et al.*, 2012). Similarly, due to the intermittent and open nature of soccer game play, the importance of reactive agility (change of velocity of direction in response to a stimulus) is stressed with regards to soccer performance (Loturco *et al.*, 2019). Whilst many of these actions are also considered 'running characteristics' (discussed above in **Section 2.2.1.1**), the absolute performance of these abilities is underpinned by strength and power qualities. Therefore, to perform these abilities effectively, soccer players must possess adequate muscular strength and power, particularly within the lower limbs (Turner & Stewart, 2014; Wisløff *et al.*, 2004). Absolute measures of sprinting ability (Jullien *et al.*, 2008; Little & Williams, 2005), jumping height and distance (Chamari *et al.*, 2008), and COD performance (Little & Williams, 2005), have been shown to differentiate between performance standards in senior soccer players; and, absolute jump height ($r = 0.78$), 10m ($r = 0.94$), and 30m ($r = 0.71$) sprint performances, have demonstrated very strong – nearly perfect relationships with 1RM back squat performance in professional male soccer players (Wisløff *et al.*, 2004). In addition, the ability to decelerate and change direction also demonstrates to strong-to-very strong relationships

with eccentric strength (Chaabene, Prieske, Negra, & Granacher, 2018). Moreover, it has been suggested that possession of improved strength qualities lessens the incidence of injury within key muscle groups during training and match play (Askling, Karlsson, & Thorstensson, 2003; Malone *et al.*, 2018).

Positional differences in strength and power characteristics are also reported within cohorts of elite soccer players. Sporis *et al.* (2009) observed forwards to be quicker over linear sprint distances of 5, 10, and 20m, and also perform better during explosive power tests (squat jump and countermovement jump) comparative to defenders. This aligns with the frequency of this movement by these positions observed during gameplay, as discussed in the previous section of this literature review (**Section 2.2.1.1**) (Bradley *et al.*, 2011; Di Salvo *et al.*, 2009). Furthermore, defenders are reported to possess greater relative strength across all positions of senior male soccer players (Stølen *et al.*, 2005; Wik, McAuliffe, & Read, 2018), corresponding with the prevalence of collisions, contacts, and tackles observed by players of this position within competition (Bloomfield, Polman, & O'Donoghue, 2007; Di Salvo *et al.*, 2009). The physical differences observed between performance standards, playing positions, and developed aligning with the demands of training and competition correspond with anthropometric and morphologic differences. Therefore, to gain a comprehensive understanding of all physical factors prevalent at the senior level of professional soccer, these too must be considered.

2.2.1.3 Anthropometric and morphologic characteristics of professional soccer

In addition to observed trends for physical characteristics and abilities, certain anthropometric and morphologic traits are also preferential for improved soccer performance. Whilst competitive soccer is certainly less stereotypical in this regard,

comparative to more unidimensional sports, anthropometric and morphologic trends are still observed within elite soccer players. Elite soccer teams are characterised with a relative homogeneity in body stature and mass. Players have been reported to be ~180 cm tall and ~75 kg body mass, on average (Bloomfield *et al.*, 2005; Lago-Peñas *et al.*, 2014; Owen *et al.*, 2018). However, subtle positional differences are reported, likely due to the positional advantages associated with possession of differing anthropometric and morphologic profiles. Goalkeepers are commonly reported to be both the tallest and heaviest players (Reilly *et al.*, 2000; Sutton *et al.*, 2009; Wik *et al.*, 2018), with varied observed differences within the literature regarding outfield players. Many researchers suggest that midfield players are shorter and lighter than both defenders and attackers, in addition to carrying less body fat (Ostojic, 2003; Sporis *et al.*, 2009). However, it has also been suggested that minimal differences may exist across all outfield positions in a congruent sample of elite soccer players (Sutton *et al.*, 2009). The apparent varied physical demands between different positions of elite soccer players are suggested to place different demands and intensity on the body (Bloomfield *et al.*, 2007). Which, when experienced to the extent that full-time professional players would, may result in different energetic costs, thus affecting body composition (Owen *et al.*, 2018). This premise is supported by observed changes in body composition across a competitive season within an elite soccer sample (Lago-Peñas *et al.*, 2014; Ostojic, 2003; Owen *et al.*, 2018). However, whilst the physical demands of training and competition are likely to vary between playing positions, the multi-dimensional nature of soccer game play require varied physical, anthropometric, and morphologic profiles to be successful at the elite level (Bloomfield *et al.*, 2005). Differences in anthropometric and morphologic variables are also typically observed between elite and sub-/non-elite players. Regardless of position, elite players tend to possess lower body fat and more lean mass than sub-/non-elite players (Reilly

et al., 2000; Wittich *et al.*, 2001). Additionally, anthropometric and body composition is reported to be associated with physical performance in soccer (Lago-Peñas *et al.*, 2014; Ostojic, 2003; Silvestre *et al.*, 2006). Similar to the development of physical characteristics within soccer during recent years, congruent advancements to the anthropometric and morphologic profiles of elite soccer players have also been observed. Comparative to early data (Ostojic, 2003; Reilly *et al.*, 2000; Wittich *et al.*, 2001), modern day soccer players are slightly taller, heavier, and possess greater fat free mass (le Gall *et al.*, 2010; Milsom *et al.*, 2015). Potential explanations for these developments could again be resultant of the increased physical demands of soccer match play, changes in volume and intensity of training, and improvements in supplementary sport science support such as nutrition, strength and conditioning, and recovery tactics employed throughout the training process (Milsom *et al.*, 2015).

2.2.1.4 Physical characteristics of professional soccer – summary

Physical demands of competitive soccer match play are a key consideration when preparing senior players for elite level competition. The nature of soccer gameplay, however, allows for divergent playing styles and varied constructs of ability to succeed within the professional ranks (Bradley *et al.*, 2011). Whilst it is apparent that positional constraints influence the importance and prevalence of various attributes important to soccer performance (Bradley *et al.*, 2011; Di Salvo *et al.*, 2009), minimum physical requirements for success within senior soccer are evident (Bradley *et al.*, 2011; Stølen *et al.*, 2005). Evidence also suggests that physical demands of soccer training and competition have increased in recent years (Barnes *et al.*, 2014; Bush *et al.*, 2015). The most notable development appears to be the prevalence of high-intensity and sprint/COD actions (Anderson *et al.*, 2016; Barnes *et al.*, 2014; Bush *et*

al., 2015). However, some physical demands of soccer match play, such as total distance covered, remain relatively unchanged since early observations reported in the literature (Barnes *et al.*, 2014; Bush *et al.*, 2015). Several explanations for these observations could be posed. Modern day soccer has seen a shift in managerial styles, implementing alternative and varied tactical approaches (such as implementation of wing backs, interchangeable positions, and possession-based football) comparative to those traditionally adopted at the elite level, and thus influencing physical demands (Schuth *et al.*, 2016). Moreover, the vast developments in sport science also observed in recent years have allowed for greater investment and attention to be placed upon supplementary science activities (eg. recovery modalities, strength and conditioning, sports nutrition, etc.) (Morgans *et al.*, 2014a). Youth coaches and practitioners appear to have acknowledged these developments observed at the senior level, and, as a result, developments in physical demands and requirements at youth level have emulated these advancements (Sarmiento, Anguera, *et al.*, 2018). Whilst the multi-faceted demands between youth-senior soccer are similar in nature, the evident technical discrepancies (i.e pitch dimensions, match duration), and physical/biological differences (i.e body size, physiological attributes) result in differing characteristics evident during training and match play. Consequently, youth soccer players must be analysed and understood, within their own right, comparative to senior and adults, ensuring appropriate identification and development practices can occur.

2.2.2 Physical characteristics of youth soccer

Youth soccer can be defined as competitive soccer during childhood and adolescence, often until 19-years of age (Stratton *et al.*, 2004). Similar to senior soccer, varied competitive levels exist, with the highest competitive playing standard being academy soccer affiliated to a

senior professional team. Academy youth soccer often runs in annual cycles, with players being recruited or released from an academy at these intervals. Commonly, it is academy players who progress to senior professional players (**see Chapter 1**), therefore research into this group is often sought after. The purpose of youth soccer is to prepare and provide exposure to young players towards a potential transition to senior training and competition. The intentions of TI and TD systems are to identify and develop young players with the potential of becoming successful senior professionals. However, priority is often given to players demonstrating superior ability at the time (Meylan *et al.*, 2010). As a result, observed increases in physical demands within senior soccer, previously discussed (**Section 2.2.1**), have influenced recruitment and training strategies at youth level, resulting in a more athletic “breed” of youth talent being identified.

Comparable to senior soccer, adequate physical qualities are required to perform the wide variety of movements and actions required during youth soccer gameplay (le Gall *et al.*, 2010), alongside enduring the accumulated physical demands required to continually recover and perform during intense periods of training and competition (Enright *et al.*, 2017; Huijgen *et al.*, 2014). Moreover, successful transition between age groups, and graduation from academy–senior ranks are reported to be influenced by physical performance characteristics (Emmonds *et al.*, 2016). Accordingly, physical demands of training and competition during youth soccer are important to acknowledge when considering progression and development of talented young players. A recent review regarding TI in soccer provides a comprehensive overview on this topic (Bergkamp *et al.*, 2019). Whilst it is acknowledged within this review that predictors (such as physical abilities) may discriminate between varied performance standards, the authors suggest that the performance of these tasks are limited in their proximity to the criterion behaviour in content and context. Whilst in agreement with this

principle, in a practical setting, specifically in Scotland, the implementation of closed-skill performance markers still occur with reference to TI and TD in soccer. Therefore, a more comprehensive understanding of their value within these processes is warranted.

When evaluating physical demands of youth soccer, consideration must be given to developmental processes experienced across adolescence, and the potential limitations present when interpreting these data (Lovell *et al.*, 2015). Similarly, disparity between youth–adult anthropometrical, morphological, and physical characteristics, may result in performance differences and adopted technical/tactical approaches when comparing the two (Deprez, Fransen *et al.*, 2014). Consequently, the predictive value of these data relative to TI may be questioned. Nonetheless, findings may prove influential when preparing appropriate TD strategies to assist with youth–senior progression.

2.2.2.1 Running characteristics of youth soccer

Despite the wealth of information available regarding running demands of senior soccer players, discussed above (**Section 2.2.1.1**), comparatively few studies report this at youth level. This is surprising, considering the potential such information may have in providing insight into TI and TD processes in soccer (Saward *et al.*, 2016). Understanding of match–running performance of youth soccer players may influence assessment protocols adopted to assess match performance, along with informing training programmes (Carling *et al.*, 2008; Doncaster, Iga, & Unnithan, 2018). Moreover, given the importance of running performance within match–play, a more comprehensive understanding of these attributes may aid the process of identifying players with the potential to become senior professionals (Waldron & Murphy, 2016).

Of the limited information available regarding match-running demands of youth soccer players, there appears to be a general trend for total distance covered to increase with age (Saward *et al.*, 2016). The total distances reported range from 4356 ± 478 m in U9 players (Goto, Morris, & Nevill, 2015) to 8867 ± 859 m in U18 players (Buchheit *et al.*, 2010). Consideration should be made, however, to the fact that match durations are shorter for younger players, and so it is considered appropriate to normalize distances covered to match time (Carling *et al.*, 2008). When this adjustment is made, differences between age groups in distance covered are still present, but are less apparent – particularly at older ages (Buchheit *et al.*, 2010). Age-related changes in high-speed metrics, however, are less clear than those observed for total distance covered. Buchheit *et al.* (2010) showed that when adjusted to match time, U18 players covered more sprinting distance ($> 5.31 \text{ m}\cdot\text{s}^{-1}$) compared with U13–U17 players. However, when individual players' peak speeds are considered to categorise speed zones, only limited differences in high-speed distance covered per minute of match play, were evident in elite youth players aged U9–U10 (Goto *et al.*, 2015) and U12–U16 (Harley *et al.*, 2010). Conversely, U13 youth soccer players have been reported to cover greater distances at very-high relative speeds compared to U15–U18 players (Mendez-Villanueva *et al.*, 2013).

Alongside age, playing position has also been reported to influence running demands within youth soccer (Buchheit *et al.*, 2010). It has consistently been reported that, similar to senior players, centre backs cover the least, and wide midfield/centre forwards cover the greatest high speed distance (Buchheit *et al.*, 2010; Mendez-Villanueva *et al.*, 2013; Pereira Da Silva *et al.*, 2007). These findings, however, were reported in senior academy players (~17 years). It is suggested that senior academy soccer players possess a mature tactical understanding of position-specific tasks, comparable to senior players, therefore observed differences

between senior academy–senior may be insignificant (Buchheit *et al.*, 2010). Nonetheless, findings from Seward *et al.* (2016) suggest these positional trends exist from as young as 8 years old. Findings from Seward *et al.* (2016) also propose that match-running performance characteristics changed in a non-linear fashion, with age and playing position influencing development. Interestingly, despite the proclaimed importance of high-intensity activity within soccer, Seward *et al.* (2016) observed greater low-speed distance coverage by retained vs. released players in their sample of 263 elite male youth soccer players across 3 soccer seasons. This finding is aligned with those of Goto *et al.* (2015), who also reported differences in low-speed running distances between retained vs. released U9–U10 elite youth soccer players. Both of these authors suggest their findings be resultant of subtle changes in movement related to successful outcomes during soccer gameplay, but potentially not identifiable by global positioning systems (GPS) used to collect these data, such as changes of direction or acceleration/deceleration. Alternatively, better pacing strategies adopted by the retained groups (due to improved tactical positioning and understanding), may also explain these findings.

The intermittent nature of youth soccer match-play requires many changes in running speed and modality. Whilst these changes are suggested to be less prevalent and less influential in youth soccer than within senior competition, prevalence of accelerations and decelerations exist within youth soccer match-play (Iacono *et al.*, 2017; Vigh-Larsen *et al.*, 2018). Youth soccer players (U17–U19) were observed to perform 81 ± 2 accelerations and 84 ± 3 decelerations during a competitive match, when evaluating an elite Danish cohort (Vigh-Larsen *et al.*, 2018). Similar to senior players, and comparative to observations regarding high-intensity activity, discussed above (**Section 2.2.1.1**), there were trends for wide midfield and strikers to perform more accelerations and decelerations than central midfielders and

defenders. However, it should be noted that this study assessed senior academy players only, therefore limits transferrable knowledge to younger cohorts of youth soccer players.

Absolute sprinting speed is also considered during discussions regarding physical demands of youth soccer game-play. Maximal sprinting speed observed during gameplay demonstrated stepwise progressions across age groups, ranging from $24.9 \pm 1.0 \text{ km}\cdot\text{h}^{-1}$ for U13 players to $31.9 \pm 1.7 \text{ km}\cdot\text{h}^{-1}$ for U18 players (Mendez-Villanueva *et al.*, 2013). These observed progressions, however, are not surprising, given the vast maturational changes occurring throughout adolescence. Contradictory to observations made for other metrics, and comparative to senior soccer, wide midfield ($29.0 \pm 2.8 \text{ km}\cdot\text{h}^{-1}$) and strikers ($29.6 \pm 2.9 \text{ km}\cdot\text{h}^{-1}$) did not possess greater maximal sprinting capacity than central defenders ($29.9 \pm 2.3 \text{ km}\cdot\text{h}^{-1}$) or central midfielders ($28.7 \pm 2.9 \text{ km}\cdot\text{h}^{-1}$) (Mendez-Villanueva *et al.*, 2013). These findings align with those of Buchheit *et al.* (2012), who report similar observations within a comparable cohort. Interestingly, this suggests that maximal sprinting capacity may be comparable across homogenous groups of youth soccer players, and that positional discrimination of this ability may not be possible during adolescence.

Whilst chronological progressions are reported in various match-running metrics with age, differences are also suggested to be associated with variations in maturity status. An advanced maturity status is suggested to positively impact maximal sprinting speed (McCunn *et al.*, 2017), improve match-running performance (Buchheit & Mendez-Villanueva, 2014), and increase the prevalence of in-game accelerations (Mendez-Villanueva *et al.*, 2011). Moreover, Murtagh *et al.* (2018) suggest that short sprint distances (10/20m) can discriminate between elite vs. control youth soccer players, when adjusting for maturity status. In contrast, Carling *et al.* (2009) report few differences between relatively older and

younger U14 players. Though these conflicting studies suggest relationships between maturity and match-running performance remain unclear, consideration of the entire bed of literature suggests that maturity status should be considered when evaluating running-demands in youth soccer (Palucci Vieira *et al.*, 2019).

2.2.2.2 Strength and power characteristics of youth soccer

Given the association between strength and power characteristics and relevant in-game high-intensity physical actions and movements (de Hoyo, Gonzalo-Skok, *et al.*, 2016; de Hoyo, Sañudo, *et al.*, 2016), alongside progressions in the prevalence of these characteristics within senior match-play (Barnes *et al.*, 2014; Bush *et al.*, 2015), substantial attention is placed upon strength and power attributes during the identification and development process of youth soccer players. However, ability to effectively produce force and demonstrate strength characteristics is suggested to be the least stable physical variable across adolescence, with priority often placed upon developing these attributes throughout maturation (Lloyd & Oliver, 2012). Historically, physical profiling in soccer has focussed on both senior players, and match-running demands. Hence, extremely limited data exist regarding the importance and prevalence of strength and power characteristics during youth soccer match-play. As discussed earlier (**Section 2.2.1.2**), strength and power characteristics are widely accepted to contribute during performance of explosive actions such as jumps, changes in direction, accelerations and decelerations, all of which are prevalent during youth soccer match performance (Buchheit *et al.*, 2010; Mendez-Villanueva *et al.*, 2013; Palucci Vieira *et al.*, 2019). Consequently, developing strength and power ability may improve effectiveness during these actions, thus improving soccer performance. Resultant of this rationale,

possession and development of these attributes is considered during the identification and development process of youth soccer players (Murtagh *et al.*, 2018).

Similar to observations reported for running demands, discussed above (**Section 2.2.2.1**), strength and power characteristics are suggested to discriminate between performance standards in youth soccer players. Gil *et al.* (2014) report differences in both COD and jump performance between preselected youth soccer players and an age matched group of fringe players. Similarly, Deprez, Valente-dos-Santos *et al.* (2015) suggest standing broad jump performance to be the largest discriminator between players progressing to first-team competitive soccer vs. those who drop out, when evaluating a range of generic physical abilities within their Belgian academy sample. Interestingly, Carling, Le Gall, & Malina (2012) found no differences in jump performance between senior academy-senior players when graduating from a youth academy to senior soccer in a longitudinal sample of elite French soccer players between 1992-2003.

When considering the role of maximal strength characteristics relative to youth soccer players, preference again has been given to senior academy players within the literature. Very strong relationships were observed between absolute strength and jump performance ($r = 0.76$) in a cohort of well-trained youth soccer players (~17 years) (Comfort *et al.*, 2014). Moreover, Gissis *et al.* (2006) report stepwise differences between elite, sub-elite, and recreational youth soccer players (~16 years) when evaluating maximal lower body isometric strength, and force relative to body mass. Opposing this, no difference was reported between standards of young soccer players (~10 years) for grip strength dynamometry by Gil *et al.* (2014). Considering the instability in strength and power characteristics reported in chronologically younger and less mature individuals (Lloyd & Oliver, 2012), alongside the vast

physical developments experienced across childhood and adolescence, anthropometric and morphologic characteristics should also be considered when evaluating youth soccer players from a physical perspective.

2.2.2.3 Anthropometric and morphologic characteristics of youth soccer

Given the vast physical developments present during adolescence, and the varied rates at which individuals experience these various progressive stages, anthropometric and morphologic characteristics are amongst the most studied characteristics of youth soccer players. Specifically, rates of growth and maturation have been studied from a TI and TD perspective, with researchers suggesting that those with an advanced maturity status (i.e. experiencing physical maturation earlier), receive preferential treatment during selection/deselection processes (Carling *et al.*, 2009; Unnithan *et al.*, 2012). Moreover, perhaps more so than observed within senior athletes, anthropometric and morphologic characteristics influence physical attributes and ability, again largely dictated by maturity status and chronological age progression (Figueiredo *et al.*, 2009). Consequently, these factors must be acknowledged when considering physical characteristics prevalent within youth soccer players.

Comparable to senior soccer, anthropometric and morphologic differences exist when comparing playing positions in youth soccer. For example, Wong *et al.* (2009) report differences in body mass and stature between playing positions within their cohort of elite academy soccer players (~13 years), with goalkeepers and defenders being significantly taller and heavier than midfield and forward players. Deprez, Franssen *et al.* (2014) report similar trends, suggesting goalkeepers and defenders to be tallest, and heaviest comparable to other playing positions. Moreover, Gil, Gil *et al.* (2007) also observed a tendency for goalkeepers to

be the tallest and heaviest players, with forwards being the shortest and possessing the lowest percentage body fat. However, Towlson *et al.* (2017) suggest that, given the inter-individual trajectories of physical development according to biological maturation, playing position allocation should be considered 'plastic' by selectors, until complete maturity is achieved. The thoughts of Towlson and colleagues (2017) are echoed by Seward *et al.* (2018) who suggest that, due to the vast changes in match skills in relation to age and maturity status, the predictive ability to pre-empt playing position during the developmental and formative years is substantially compromised.

Again, comparable to observations in senior soccer players, anthropometric and morphologic differences are also suggested to be present when comparing playing standards of youth soccer players. Cripps *et al.* (2017) found that talent identified individual's possessed greater standing stature and an advanced maturity status than non-talent identified groups of U16 Australian soccer players. Gravina *et al.* (2008) report that first team players were taller and heavier than reserve players in their sample of U10-U14 Spanish elite academy players. Similarly, Rebelo *et al.* (2013) found elite players to be taller and heavier than non-elite players across all playing positions within their sample of U19 Portuguese soccer players. Conversely, le Gall *et al.* (2010) report minimal differences in body mass, stature, body fat percentage, or skeletal age between international, professional, and amateur youth soccer players (U14-U16). Deprez, Franssen *et al.* (2015b) also report no clear trends for stature, maturity status, or body mass when evaluating a longitudinal retrospective study of professional Belgian soccer players who either progressed or dropped out of their respective soccer clubs at various age groups (U10-U17), or between U17 players who received a professional contract vs. those who did not. Moreover, Vaeyens *et al.* (2006) report no differences between stature, body mass, or body fat percentage between elite, sub-elite, and

non-elite Belgian youth soccer player (U13-U16). Whilst there appear to be trends for anthropometric and morphologic differences between youth soccer players of a higher playing standard, these observations appear inconsistent.

Unsurprisingly, a wealth of evidence exists demonstrating anthropometric changes during chronological age progression. Deprez, Fransen *et al.* (2014) report stepwise increases in both stature and body mass across age groups U11-U19. Similarly, Gravina *et al.* (2008) report comparable findings, with developments in stature and body mass with chronological age progression. In recent years, however, the role of physical maturation relative to performance and selection/deselection bias has been thoroughly discussed. It is proposed that, resultant of the varied rates of maturational development occurring during adolescence, the timing and tempo of these changes may substantially influence acute performance and both short- and long-term decision making regarding youth soccer players (Meylan *et al.*, 2010). Whilst the maturation process is one associated with the biological and physical progressions in chronological age (Meylan *et al.*, 2010), discrepancies in maturity status are widely reported to exist within-age groups, with players of comparable chronological age displaying substantial differences in maturity status (Malina *et al.*, 2005; Malina, Figueiredo, & Coelho-Silva, 2017). Advanced age and/or maturity often result in developments in anthropometric and morphologic variables. For example, early maturing individuals were taller, heavier, and possessed a higher skeletal age than those with on time or late maturity status, when evaluating elite players from a French soccer academy (Carling *et al.*, 2012). Similarly, both Figueiredo *et al.* (2009) and le Gall *et al.* (2010) report that individuals with a progressed maturity status had higher body mass, greater standing stature, and greater leg length (specifically between U13-U15 age groups) when evaluating samples of youth soccer players. Moreover, Figueiredo *et al.* (2009) observed progressed maturity status and advanced

anthropometrics specifically within their 'elite' sample group comparative to non-elite youth soccer players.

Greater anthropometric values have also been associated with improvements in physical attributes amongst adolescent and developing youth athletes. For example, Wong *et al.* (2009) report moderate–strong relationships between body mass/height and a range of measures of physical fitness. Similarly, both Gravina *et al.* (2008) and Carling *et al.* (2009) found comparable relationships between standing stature/body mass and performance on a range of generic fitness tests.

Aligned with observations for anthropometric and morphological differences regarding maturity status and chronological age, differences are also reported within-age groups for birth quarter distribution. This has been extensively shown to influence decisions around selection and recruitment of youth soccer players (discussed in **Section 2.1.3.2**), thus directly influencing TI and TD. Figueiredo *et al.* (2018) report those born in the 1st birth quarter possessed a higher skeletal age, greater standing stature, and higher body mass than those born in the remaining birth quarters across the year (2nd–4th). Similarly, Fragoso, Massuca, & Ferreira (2015) found those born in the first half of the year (quarters 1 & 2) were taller and heavier than those born in the second half of the year (quarters 3 & 4) from their sample of U15 Portuguese soccer players. These findings are comparable to those of Carling *et al.* (2009) and Hirose (2009) who report those born in earlier quartiles of the year had greater standing stature, higher body mass, and higher skeletal age, comparable to those born in later quartiles. These findings support the notion that, generally, chronologically older individuals within age groups (those born in the first and second quartiles) possess a more advanced maturity status than their chronologically younger teammates. This premise is evident across

all age groups of youth soccer players ranging from observations in U18 elite Spanish soccer players (Del Campo *et al.*, 2010), to findings from Müller *et al.* (2018), who observed relationships between physical discrepancies and birth placement apparent as young as U9 in elite youth soccer players.

Anthropometric and morphologic characteristics appear to be amongst the most influential factors regarding decision making and selection/deselection of youth soccer players. Interestingly, several tendencies, comparative to observations made at the senior level, are evident within youth soccer. However, the accuracy and suitability of this approach is questioned. Due to the vast physical developments occurring across adolescence, both regarding physical maturation, and chronological age progression. It appears that consideration must also be made to both the timing and tempo of these developments, and the varied inter-individual rates by which these occur, when evaluating the characteristics of youth soccer players.

2.2.2.4 Physical characteristics of youth soccer – summary

Childhood and adolescence provide opportunity to develop physical skills and capacities relative to both short- and long-term sporting success (Lloyd & Oliver, 2012). Whilst review of the literature highlights many similarities between youth–senior soccer, many discrepancies and variations in demands are evident when considering a youth sample. Performance and anthropometric/morphologic differences are present within youth soccer players of varied playing position as young as 8 years old (Saward *et al.*, 2016; Saward *et al.*, 2018). This suggests that both inter-positional physical trends are apparent across the youth–senior continuum, and, that decision-making regarding positional allocation and suitability is being

influenced early within childhood. Whilst this approach is questioned (Towlson *et al.*, 2017), considerable evidence exists demonstrating its prevalence.

It has, on several occasions, been suggested that discrepancies in physiology between adult and youth athletes require different approaches than simply treating youth athletes as 'miniature adults' (Matos & Winsley, 2007). The vast physical developments experienced throughout chronological age progression substantially alter physical capacity, and the prevalence of characteristics during match-play (Carling *et al.*, 2009; Gravina *et al.*, 2008). Moreover, discrepancies in rules and constraints comparative to senior soccer exist within youth match-play, further influencing physical demands and characteristics (Buchheit *et al.*, 2010; Carling *et al.*, 2008). Consistent evidence exists that physical characteristics can discriminate between performance standards of youth soccer player (Unnithan *et al.*, 2012; Vaeyens *et al.*, 2006). However, consideration must be made to discrepancies in both chronological age and maturity status (Deprez, Franssen *et al.*, 2014; Meylan *et al.*, 2010). Accordingly, both the specific physical demands and characteristics of youth soccer, alongside the unique physical developments experiences throughout childhood and adolescence must be acknowledged when evaluating youth soccer players from a physical perspective.

2.2.3 Physical characteristics of soccer – summary

- Due to the multi-faceted nature of soccer, a vast range of physical characteristics are required to succeed during training and competition.
- Whilst demands and characteristics can substantially vary dependent on a range of factors (such as age, maturity status, playing position, playing style), abilities across a range of physical traits may differentiate between performance standards at both youth (Vaeyens *et al.*, 2006) and senior (Sporis *et al.*, 2009) level.

- Evidence exists regarding the increase in physical demand of modern day soccer in recent years (Barnes *et al.*, 2014; Bush *et al.*, 2015), highlighting the importance of these characteristics.
- Consideration must be made to discrepancies between youth and senior soccer when considering physical characteristics, both in terms of match demands (Palucci Vieira *et al.*, 2019) and physical characteristics/capacities (Grossmann & Lames, 2015) of these samples.
- Caution must be taken when discussing physical characteristics and demands of youth–senior soccer concurrently.
- Given the apparent biological and physiological differences between youth– senior (Figueiredo *et al.*, 2009; Rebelo *et al.*, 2013), it is imperative that physical performance measures and methods applied are accurate, reliable, and valid for the sample they intend to assess.
- Whilst it is important to acknowledge that physical characteristics are but one of a myriad of contributing attributes associated with identification and success within the sport of soccer (Sarmiento, Anguera, *et al.*, 2018; Unnithan *et al.*, 2012; Williams & Reilly, 2000), appropriate evaluation and measurement of physical characteristics and capacities may provide valuable information relative to the TI and TD of soccer players.

2.3 Physical performance testing in soccer

Given an appreciation and understanding of the technical demands and characteristics of importance for soccer training and competition, provided by the previous section of this literature review (**Section 2.2**), steps can be made towards identifying appropriate means and methods of assessment. Similar to general principles of testing and measurement technique (Winter *et al.*, 2007), consideration must be made to the specificity of tests (relative to sporting demand and individual requirements), and the quality of the measures (i.e. reliability, validity, and sensitivity). To be considered an appropriate measurement tool, implemented tests must: i) possess acceptable levels of error to provide meaningful information regarding the variable of assessment (reliability) (Atkinson & Nevill, 1998); ii) assess what it intends to measure (logical validity), be comparable to a gold-standard measure (criterion validity), discriminate between distinct performance standards (construct validity) (Currell & Jeukendrup, 2008), and; iii) possess sensitivity to detect the smallest worthwhile change in performance (Hopkins, Hawley, & Burke, 1999). Historically, the quality of testing procedures have been validated in senior athletes, yet implemented within a youth sample based upon this unrepresentative validation (Paul & Nassis, 2015a). As addressed in the previous section of this literature review, substantial physical and biological discrepancies between youth–senior athletes exist. Therefore, acknowledgement of these discrepancies should be made when implementing measures of assessment. Consequently, if these measures are to be adopted as part of an assessment battery towards informing the TI and TD process, a comprehensive understanding of the suitability of these measures should be held by researchers and practitioners. The subsequent sections of this literature review will discuss measures utilised to assess physical characteristics prevalent in soccer, specifically addressing their suitability to assess child–youth populations.

2.3.1 Evaluating running characteristics of soccer

Aligned with observations of running characteristics and demands in soccer, evaluation of running characteristics has taken precedence when considering testing procedures examining physical attributes relative to soccer training and match play. Whilst it is well established that soccer performance is multi-faceted in its physical requirements (Stølen *et al.*, 2005), the energy provision required for match play performance is predominantly derived from aerobic energy sources (Doncaster, Iga, *et al.*, 2018). Consequently, preference specifically has been placed upon assessing endurance running performance during physical assessment of soccer athletes. As previously discussed (**Section 2.2.1.1**), the increase in importance and prevalence of high intensity activity observed during match play, such as sprinting and changes of direction, has been reported (Barnes *et al.*, 2014; Bush *et al.*, 2015). Therefore, an ability to accurately and effectively assess these characteristics is also required as part of the assessment and evaluation process of preparing soccer players. Accordingly, assessment of both endurance and maximal speed running abilities are commonly implemented by soccer researchers and practitioners.

2.3.1.1 Evaluating running characteristics of soccer – endurance

Historically, endurance running ability has been assessed via a maximal, incremental treadmill test, assessing maximal aerobic capacity (VO_{2max}) (Impellizzeri, Rampinini, & Marcora, 2005). However, the requirement for expensive equipment and practitioners with expert knowledge of specific methods resulted in only professional clubs and those associated with higher education institutions being able to access these tests. Whilst a laboratory-based VO_{2max} test remains the gold-standard for assessing maximal aerobic capacity within athletic populations (Impellizzeri *et al.*, 2005), more recently, a range of field-based measures assessing endurance

running performance have been adopted by researchers and practitioners (Buchheit, 2008; Krusturp *et al.*, 2003, 2006). Specifically, these tests rose to popularity due to their intermittent nature and application in a field-based environment, allowing for a more appropriate assessment of running performance comparative to soccer demands alongside a wider spread of practitioners being able to assess and evaluate their players. At the turn of the century, Krusturp *et al.* (2003) examined the physiological response and reproducibility of the Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT L1), initially proposed by Bangsbo (1994), and its application to elite soccer. The YYIRT L1, is an intermittent running test requiring participants to repeatedly perform 2 x 20m sprints including a 180° turn, separated by short rest periods. The test is dictated by an audible bleep, indicating when participants should start, turn, and complete each shuttle run. As the test progresses, running speed increases, and participants complete the test at the point whereby they cannot complete the shuttle runs within the dictated timings. The YYIRT L1 demonstrated nearly perfect reproducibility in Krusturp *et al.* (2003) sample of senior elite male soccer players ($r = 0.98$; CV = 4.9%). Moreover, very strong relationships were observed between the YYIRT and both maximal aerobic speed ($r = 0.79$) and maximal oxygen uptake ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) ($r = 0.71$) during a maximal incremental treadmill running test. Finally, very strong relationships were also observed between performance on the YYIRT L1 and high-intensity running performed within a soccer match (m) ($r = 0.71$). The authors concluded that the YYIRT L1 is a valid measure of endurance running performance in soccer, taxing both the aerobic and anaerobic energy systems due to the interspersed short recovery intervals within the test. Following publication of this validation study by Krusturp *et al.* (2003), the YYIRT L1 was widely implemented to assess endurance running performance in both senior (Castagna *et al.*, 2006; Rampinini *et al.*, 2010) and youth (Castagna *et al.*, 2009; Markovic & Mikulic, 2011) soccer

athletes. However, until more recently (Deprez, Fransen *et al.*, 2015a; Deprez, Coutts, *et al.*, 2014), the suitability of the YYIRT L1 to assess a developing child–youth sample was assumed, with limited empirical evidence to support its implementation. Deprez, Coutts, *et al.* (2014) investigated the test-retest reliability and construct validity of the YYIRT L1 in a sample of youth soccer players (age: 11-17 years). Whilst the authors suggest the YYIRT L1 to possess excellent reproducibility across their entire sample (ICC = 0.82 – 0.94), they observed greater variability in test performance for younger participants within their sample (U13: CV = 17.3%; U17: CV = 7.9%). Moreover, Deprez, Coutts, *et al.* (2014) observed significant performance differences between elite/non-elite players (in favour of elite players) across all age groups included within their sample, reporting differences in performance of: U17 – 30.3%, U15 – 61.2%, U13 – 31.2%. Consequently, the authors support the use of the YYIRT L1 as a reliable measure of soccer specific running performance and promote its use for the comparison of young soccer players of varied ability. However, note the potential lower reliability observed within the younger participants within their sample. The following year, Deprez, Fransen *et al.* (2015a) supported their previous findings, reporting similar observations regarding the reproducibility (ICC = 0.87 – 0.95) and reliability (CV = 3.0 – 7.5%) of the YYIRT L1 in a comparable cohort of high-level youth soccer players.

Following validation of the YYIRT L1, Krstrup *et al.* (2006) conducted a comparable study evaluating the physiological response and reliability of the Yo-Yo Intermittent Recovery Test – Level 2 (YYIRT L2) (Bangsbo, 1994). The YYIRT L2 offers a shorter-duration, higher intensity, and lower recovery alternative to the YYIRT L1 (Krstrup *et al.*, 2006). Whilst the YYIRT L2 displayed similar reliability to the YYIRT L1 (CV = 9.6%) alongside an ability to differentiate elite > non-elite players (+37%), it was suggested that the YYIRT L1 may provide a more representative indication of endurance running performance relative to the demands of

soccer (Castagna *et al.*, 2010; Krstrup *et al.*, 2006). Moreover, during direct comparison of the two tests, Fanchini *et al.* (2014) found the YYIRT L1 to be more reliable and more responsive to training than the YYIRT L2.

It is suggested that the vast differences in physical demands and action of goalkeepers in soccer generally results in exclusion from performing the traditional YYIRT (Padulo *et al.*, 2015), with calls for validation of a more appropriate measure to the physical requirements of this position. Recently, progression has been made towards validating a goalkeeper specific adaptation of the YYIRT (Ehlert *et al.*, 2018). Ehlert *et al.* (2018) report excellent reliability in their cohort of senior NCAA male goalkeepers (ICC = 0.98; CV = 5.8%). However, no comparison to in-game metrics were made, leaving questions regarding the validity of this measure.

Although endurance running demands of soccer have largely been assessed by the YYIRT L1/L2 (Impellizzeri *et al.*, 2005; Paul & Nassis, 2015a; Turner *et al.*, 2011), more recently, implementation of the 30-15 intermittent fitness test (30-15_{IFT}) (Buchheit, 2008) has been proposed for assessing intermittent endurance running performance. Whilst performance on the 30-15_{IFT} demonstrated a strong relationship with VO_{2max} ($r = 0.68$), the rationale behind the 30-15_{IFT} was to elicit a maximal running speed (MRS) reflecting the multiple physiological qualities prevalent when performing intermittent shuttle runs, to be used to individualise high-intensity interval training (Buchheit, 2008). Consequently, the 30-15_{IFT} may be better suited as a training and monitoring tool within TD. Similarly, shorter sub-maximal alternatives to the YYIRT L1/L2 have also been proposed, allowing for more regular assessment of players' training status without imposing large additional training load or time constraints (Buchheit, 2014). One such test, is a 6-min variation of the YYIRT L1 (Bangsbo, Iaia, & Krstrup, 2008). A

recent study by Doncaster, Scott, *et al.*, (2018) reports excellent reliability of this measure within a cohort of highly trained, English academy youth soccer players (ICC = 0.95-0.98; CV = 1.1-1.3%; TE: 0.96-2.44). Whilst the authors promote the 6-min YYIRT L1 as a viable non-exhaustive option for regular assessment of intermittent endurance running performance within highly trained youth soccer players, the ability of this measure to provide information regarding recovery capacity, comparable to the YYIRT L1, remains uncertain.

As with all test measures, consideration must be made to potential confounding factors which may influence the applicability of these measures congruently across both youth–senior populations. The first obvious consideration is that of physical and biological maturation differences between youth–senior, and also within a diverse age range of youth soccer players. Whilst obvious performance differences exist when comparing youth–senior performance on intermittent endurance running tests, performance by senior academy players (~18 years) on the YYIRT L1 is comparable to that of senior soccer players (Markovic & Mikulic, 2011), similar to observations of match-running performance (Saward *et al.*, 2016). Interestingly, Doncaster, Iga, & Unnithan (2018) suggest that players of an advanced maturity status do not outperform their less mature counterparts in a range of measures and determinants of aerobic fitness, with the pre-PHV (peak height velocity) group displaying a superior running economy at relative submaximal running speeds. This suggestion support the findings of Deprez, Coutts, *et al.* (2014) and Deprez, Valente-dos-Santos, *et al.* (2014) who also report no influence of maturity status on performance during the YYIRT L1. When considering the reliability and reproducibility of performance on a given measure, consideration toward the presence of a learning effect should be given (Hopkins, 2000). Resultant of the influence that sufficient familiarisation may have on performance during maximal intermittent running tests (Doncaster, Scott, *et al.*, 2018; Enright *et al.*, 2017),

researchers suggest that tests such as the YYIRT L1 be preceded by at least 1 pre-test prior to collecting data from this measure.

2.3.1.2 Evaluating running characteristics of soccer – linear sprint speed

Alongside the importance of intermittent, high intensity, repeated running within soccer match play, good maximal sprinting speed is also highly desirable in elite soccer players (Andrzejewski *et al.*, 2013). Although only approximately 1-12 % of total distance and 0.5-3.0% of playing time consists of sprint based activity during observations of senior professional soccer players (Rienzi *et al.*, 2000; Strudwick *et al.*, 2002), 67 % of goals from the top German professional league were preceded by ≥ 1 sprint or acceleration, stressing the importance of sprinting to key performance indicators in soccer (Faude *et al.*, 2012). Sprint performance across both short and long distances has been assessed to evaluate acceleration (short-distance sprints) and maximal running speed (long-distance sprints) (Haugen & Buchheit, 2016). Whilst the use of GPS metrics are appropriate to assess total accumulated sprint distance with a match, the reliability and validity of these metrics to accurately assess shorter sprint distances (<30 m), is questionable (Akenhead *et al.*, 2014; Buchheit *et al.*, 2014; Jennings *et al.*, 2010). For example, Akenhead *et al.* (2014) found that reliability and validity of 10Hz GPS was inversely related to acceleration, with accuracy of accelerations over $4 \text{ m}\cdot\text{s}^{-2}$ being compromised. Similarly, Jennings *et al.* (2010) observed a negative relationship between reliability of GPS metrics, and running speed. Consequently, photocell timing systems have been predominantly been used to assess linear sprint ability in an isolated and maximal fashion within team sports (Haugen & Buchheit, 2016).

Selection of appropriate distances should also be considered when evaluating linear speed within soccer players. Sprinting ability over short ($\leq 10 \text{ m}$) and longer ($\geq 30 \text{ m}$) distances are

considered by many researchers to require separate and specific biomechanical and neuromuscular qualities, thus warranting individual assessment (Little & Williams, 2005; Mendez-Villanueva *et al.*, 2011). Distances of 5-10 m are generally selected when examining short distance sprint ability in soccer players, following prevalence of these distances observed during senior match play (Di Salvo *et al.*, 2009; Di Salvo *et al.*, 2010). Short-distance sprints (0-10 m) are more prevalent in youth than senior soccer (Mendez-Villanueva *et al.*, 2011, 2013), with longer sprints (>20 m) observed less frequently in a youth cohort. Whilst distances of 60 m are required to achieve maximal running speed in adult athletes (Haugen & Buchheit, 2016), shorter distances (20-40 m) are commonly selected during evaluation of maximal running speed within soccer due to observed maximal sprint distances performed in competition (Andrzejewski *et al.*, 2013; Di Salvo *et al.*, 2010). Moreover, Buchheit *et al.* (2012) suggest that running speed in young soccer player's plateaus after 4-5 s, suggesting that distances of 40 m are adequate to assess maximal running speed in this cohort.

Resultant of the varying technology and unaccounted extraneous variables that may affect sprint running performance, stringent methodologies are required in order to observe 'true' changes in performance. A range of photocell timing systems are commonly implemented to assess linear sprint performance over both short- and long-distances. Specifically, comparison has been made between single- and dual-beamed photocells. A potential limitation of single-beamed photocells is the potential for the beam to be broken by arm swing, thus providing inaccurate timings for sprint performance. To combat this, Cronin & Templeton (2008) suggest that practitioners position photocells at an appropriate height to minimise this error. For example, Yeadon, Kato, & Kerwin (1999) report inappropriate breaking of timing beams in 60 % of cases when single-beam photocells were mounted at chest height, whereas single-beam photocells mounted at hip height were inappropriately broken in just 4 % of cases.

Moreover, inspections of typical reliability of single-beam photocells reveal 0.03 s SEM and ~2% CV during short-sprint distances (Moir *et al.*, 2004). For dual-beamed photocells, both beams have to be broken at the same time, therefore minimising chance of inappropriate breaking of beams by arm swing or similar (Haugen & Buchheit, 2016). As a result, improved accuracy of these systems are reported comparative to single-beamed photocell systems during short-distance sprinting (SEM = 0.02 s; CV = ~1%) (Earp & Newton, 2012; Haugen *et al.*, 2014).

Regardless of technology adopted, several procedural considerations should be acknowledged when evaluating linear sprint performance. Firstly, start positions should be standardised, and appropriate to the sample, due to potential performance differences when implementing varied start positions (Altmann *et al.*, 2015; Duthie *et al.*, 2006). Commonly, crouch starts are adopted within team sports due to participants' familiarity with this start position, and an ability to position timing cells appropriately and consistently as per the sample group (Buchheit *et al.*, 2012). Conducting multiple trials of linear sprints are also encouraged to ensure a representative value is obtained for each individual, with 2-4 trials encouraged for sprint distances of 5-40 m (Haugen & Buchheit, 2016). Similarly, whilst consideration should be given to whether the best or average values are selected when monitoring sprint performance, Al Haddad, Simpson, & Buchheit (2015) found comparable differences between both best and average values when monitoring sprint development in youth soccer players. The distance of sprints performed substantially influence the prevalence of technological and procedural factors. Short-distance sprints are considerably more sensitive to procedural or methodological error. Whilst time differences caused by these factors are trivial-small in isolation, in combination, these variables can cause moderate-large differences (Haugen & Buchheit, 2016). Accordingly, practitioners and researchers should

strive to minimise potential error by appropriate and accurate set up and interpretation of results.

Finally, consideration should also be made to environmental factors to ensure accurate and representative linear sprint values are obtained. Appropriate and standardised clothing and footwear is encourage during linear sprint evaluation to avoid restriction to movement (clothing) and appropriate traction and contact with the running surface (footwear) (Haugen & Buchheit, 2016). Similarly, standardised running surface is advised when evaluating linear sprint performance, due to observations of performance discrepancies between varied running surfaces (Gains *et al.*, 2010). Moreover, appropriate and consistent temperature and weather conditions are advised to remove potential effects to performance. Commonly, testing protocols are encouraged to be conducted indoors, and at a constant temperature ~22° C (No & Kwak, 2016).

2.3.1.3 Evaluating running characteristics of soccer – COD/agility

Comparable to the importance of linear sprint ability, the ability to efficiently change direction and velocity is also of significance to soccer performance (Pojskic *et al.*, 2018), due to its multi-dimensional nature (Stølen *et al.*, 2005; Strudwick *et al.*, 2002). As discussed previously (**Section 2.2.1.1**), high intensity activity (including sprinting, accelerations, decelerations, and COD) has increased substantially during match play in senior soccer (Barnes *et al.*, 2014; Bush *et al.*, 2015). Whilst advancements in modern day technology allows for in-game measurement and analysis of high-intensity activity (including multi-directional running) via GPS systems, several limitations in this approach have been posed by researchers. For example, Jennings *et al.* (2010) suggest the GPS systems may be limited for the assessment of efforts involving change of direction. Similarly, both Buchheit *et al.* (2014) and Akenhead

et al. (2014, 2013) critique the accuracy of GPS systems to accurately and reliably capture the number of accelerations/decelerations within competition – both of which are prevalent during multi-directional running. Moreover, utilisation of GPS data may provide global information, however, provide no detailed insight regarding potential asymmetries or imbalances for consideration during the training process (Bishop, Turner, & Read, 2018). Finally, whilst wearable GPS systems are able to quantify the volume and incidence of high-intensity, multi-directional running within training and competition, they are unable to provide precise and measurable feedback on maximal capacity or quality of change of direction (COD) and agility performance.

Alongside assessment of linear sprinting, assessment of COD and agility is commonly implemented during evaluation of soccer athletes within isolated and dedicated tests (Paul, Gabbett, & Nassis, 2016). Although COD and agility have been wrongly used interchangeably in the literature (Young, Dawson, & Henry, 2015), the main discriminating factor between the two appears to be the prevalence of a stimulus instigating the change in direction within agility performance (Sheppard & Young, 2006; Young *et al.*, 2015). Accordingly, agility has been defined in the literature as “a rapid whole body movement with change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006). On the other hand, whilst movement demands appear comparable to those of agility performance, COD assessment is conducted in a pre-planned fashion (Nimphius *et al.*, 2018; Spiteri *et al.*, 2015). Researchers suggest both skills to be important and prevalent within sporting performance of team sport athletes, however, many suggest that the prevalence of a stimulus better aligns to the demands of competition (Sporis *et al.*, 2010). Resultant of these discrepancies, COD and agility have been classified as independent skills warranting distinct and individuals methods of assessment (Young *et al.*, 2015).

When assessing COD ability, a variety of methods can be implemented varying in duration, distance, number of COD's performed, physical requirement, and energy systems utilised (Nimphius *et al.*, 2018). Whilst in some sports, where COD performance is a prevalent component of task performance (such as runs in cricket from the batsmen – Lockie, Callaghan, & Jeffriess, 2013, and; baseball/softball: batsmen running to bases – Nimphius, McGuigan, & Newton, 2010), sport specificity may be required when selecting COD tests, many practitioners implement COD tests to assess ability of physical capacities challenged during test performance (Nimphius *et al.*, 2018). For example, many COD tests assess COD ability across a 180° angle of direction change (eg. 505 COD test, modified 505 COD test, pro-agility) (Nimphius *et al.*, 2018), challenging the ability to accelerate and decelerate harshly during the test and associated strength qualities (particularly eccentric strength) (Nimphius *et al.*, 2016). In comparison, other COD tests assess ability across 45-90° angles of direction change (eg. T-Test, Illinois agility run, Y-sprint drill) (Nimphius *et al.*, 2018), allowing for emphasis on maintenance of speed throughout the test (Spiteri *et al.*, 2015).

During assessment of agility performance, comparable tests to COD assessment are administered, with the addition of a stimuli to initiate the change in direction. Commonly, T- or Y-shaped sprints are performed, requiring a 45-90° angle of direction change using either human (Morland *et al.*, 2013; Scanlan *et al.*, 2014), video (Farrow, Young, & Bruce, 2005; Spiteri *et al.*, 2015), or light (Oliver & Meyers, 2009; Sekulic *et al.*, 2014) stimuli. Implementation of appropriate stimuli is considered important to both the validity of the task, and upon exhibiting the desired physical loading during the COD portion of this test (Lee *et al.*, 2013; Nimphius *et al.*, 2018). Although commonly utilised within training drills, light stimuli are reported to increase joint loading beyond that of 2D and 3D stimuli (Lee *et al.*, 2013). Moreover, use of generic light stimuli fail to allow for assessment of sport-relevant

perceptual-cognitive ability (Oliver & Meyers, 2009; Young & Farrow, 2013). Whilst video stimuli allow for controlled, reliable, sport-specific stimuli to be exhibited to athletes during agility test performance, the ability to consistently replicate and administer this mode of test within practice, is limited. In addition, reliability of human stimuli is questionable, largely dependent on the experience and competence of the tester (Spiteri, Cochrane, & Nimphius, 2012). Although physical actions constitute the greatest proportion of time to complete an agility test (Mendez-Villanueva *et al.*, 2011), the perceptual-cognitive ability to effectively process and utilise contextual information has been reported as one of the strongest contributors to elite/sub-elite discrimination in team sports (Scanlan *et al.*, 2014; Ward & Williams, 2003; Williams & Davids, 1998). Therefore, it is suggested that the ability to measure reaction time/decision-making time be possible when conducting and extracting data from agility tests. Although perceptual-cognitive and decision-making ability is championed with regards to its importance within agility performance, large-very large relationships with linear sprint performance have been consistently demonstrated within the literature (Gabbett, Kelly, & Sheppard, 2008; Nimphius *et al.*, 2013; Nimphius *et al.*, 2010). This suggests that whilst perceptual-cognitive and decision-making ability is of utmost importance within agility performance, physical factors are also extremely important during execution of this skill.

Additional to the type of stimulus selected during agility assessment, several other considerations should be acknowledged when conducting COD and agility tests. Due to the complexity of movement and varied physical and reactive/perceptual-cognitive demands prevalent within COD/agility performance, specific attention to appropriate familiarisations and potential restrictions to performance of some populations should be considered. Recently, it has been suggested by Taylor *et al.* (2018) that COD performance was more variable in youth soccer players than previously reported within senior athletes. The authors

(Taylor *et al.*, 2018), suggest the onset of ‘adolescent awkwardness’ (a temporary loss in coordination during periods of rapid growth) prevalent during phases of advanced maturation experienced around peak height velocity (PHV) (Lloyd *et al.*, 2015; Philippaerts *et al.*, 2006), combined with physical complexity of their COD tests, may explain performance variance. Similarly, Lyle *et al.* (2015) suggest that those possessing better lower extremity dexterity performed better within an agility test when assessing adolescent soccer athletes. Due to the complexity of the task and demands of COD/agility tests, several authors stress the importance of adequate familiarisation prior to assessment (Paul *et al.*, 2016). Young *et al.* (2011) suggest that the lack of familiarisation was a potential explanation for the low levels of reliability (ICC = 0.10-0.33) observed within their study of Australian footballers. On the contrary, Oliver & Meyers (2009) suggest that no familiarisation period is necessary, resultant of the low variance (CV = 3.0%) observed across all trials of their agility test.

To conclude, whilst assessment of multi-directional running performed during competition may be possible via GPS systems, limited information of the quality and efficiency of COD/agility abilities are possible via this method. When assessing COD/agility, task/sport specificity should be considered, alongside the qualities the test intends to measure. Furthermore, comparable to the assessment of other running abilities, careful selection and control of methods should be present, ensuring obtained results are accurate and reliable.

2.3.2 Evaluating strength and power characteristics of soccer

Alongside assessment of the various running characteristics evident within the sport of soccer, the evaluation of strength and power characteristics is also prevalent during a physical testing battery of soccer players. Given the contribution that strength and power characteristics have on various physical (Andrzejewski *et al.*, 2013) and technical (Faude *et*

al., 2012) parameters during match-play, alongside an increase in high-intensity activity observed during competition (Barnes *et al.*, 2014; Bush *et al.*, 2015), the value of assessing these qualities is ever-increasing. Accordingly, assessments of both strength and power characteristics, individually, are commonly implemented by soccer researchers and practitioners.

2.3.2.1 Evaluating strength characteristics of soccer

Previous research has indicated that muscular strength may be as important as anaerobic power for both performance and injury prevention in soccer players (Lehance *et al.*, 2009). Moreover, given the reported relationships between muscular strength and a range of performance related attributes (such as sprinting/jumping – Comfort *et al.*, 2014; Wisløff *et al.*, 2004, and; COD – Dos’Santos *et al.*, 2017b; Fiorilli *et al.*, 2016), assessment of this characteristic is common when assessing physical abilities of soccer players. Regular testing and monitoring of an athlete’s strength characteristics can be used to prescribe and adapt training programmes to provide an optimal training stimulus (McMaster *et al.*, 2014). Traditionally, strength characteristics for team sport athletes have been assessed in a gym environment, evaluating either dynamic, isometric, or reactive strength qualities (Suchomel *et al.*, 2016). The assessment of dynamic strength is typically the most common and relevant method of assessing strength characteristics for team sport athletes, generally assessed via a repetition maximum (RM) test (Comfort *et al.*, 2014; Thomas *et al.*, 2015; Wisløff *et al.*, 2004). Dynamic strength tests may be viewed as more relevant to an athlete’s abilities due to their similarities to movements completed during competition (Suchomel *et al.*, 2016). Moreover, given the prevalence of strength and conditioning within modern day soccer training (Turner & Stewart, 2014), many athletes may be accustomed to exercises selected during RM testing.

Many studies have also adopted the use of isometric strength assessments when evaluating strength characteristics of team sport athletes. While these tests do not provide a maximum load lifted (limiting translation into dynamic strength training programmes), previous research has displayed notable relationships between isometric strength and both performance characteristics (Requena *et al.*, 2009; Thomas *et al.*, 2015), and dynamic strength performance (Bazyler, Beckham, & Sato, 2015; McGuigan *et al.*, 2010). Isometric strength exercises are commonly implemented within team sport environments due to low time and fatigue cost (Suchomel *et al.*, 2016). Moreover, isometric strength exercises may provide a truer representation of “maximum” strength of the given muscle/movement pattern, due to minimal technical requirement of the exercise (Bazyler *et al.*, 2015). Recent work by Brownlee *et al.* (2018) suggest that assessment of isometric maximal voluntary force characteristics (using an isometric mid-thigh pull) differentiates between elite vs. control youth soccer players, however, suggest that this method of training may be insufficient to elicit adaptation in isometric strength.

Finally, another common assessment of strength within team sport athletes is via hand-held dynamometry (HHD) (Amaral, Mancini, & Novo Júnior, 2012; Paul & Nassis, 2015b). HHD assessment has become an increasingly popular, cost-effective, and easy-to-use method that can overcome the technical prerequisites and equipment demands of traditional dynamic and isokinetic strength assessments (Thorborg *et al.*, 2010). Despite assessing different muscle groups than those used within soccer competition, performance on HHD displayed strong relationships ($r = 0.61$) to hamstring and quadriceps torque in a sample of professional soccer players (Whiteley *et al.*, 2012). Furthermore, HHD has demonstrated good-excellent reliability for both intra- (ICC = 0.70-0.89) and inter-rater (ICC = 0.71-0.87) measurement (Fulcher, Hanna, & Raina Elley, 2010). Given its simplicity to perform, implementation of HHD has been

championed when assessing population groups unfamiliar with strength exercises (such as youth and untrained samples) (Leyk *et al.*, 2007).

Similar to the adoption of other test measures, when selecting appropriate strength measures, we must ensure that the test is valid, reliable, and sensitive to provide meaningful information relative to their population. Considering the biological changes that occur during growth and maturation (Malina *et al.*, 2005), certain physical assessments may be more suitable for implementation within youth soccer players at different stages of growth and maturation. Moreover, Lloyd & Oliver (2012) suggest that muscular strength is the least stable physical characteristic during the developmental and formative years. Consequently, these factors should be considered when planning strength assessments within this sample. Potential limitations to strength evaluations have also been suggested, due to the limited training history and underdeveloped strength and motor capacities of youth athletes (Vandendriessche *et al.*, 2012; Vandorpe *et al.*, 2012). Therefore, reliability of performance in this group may be compromised. Finally, several historical and philosophical reservations have been reported towards the appropriateness and application of strength training/assessment within a youth cohort. Where many questioned the safety of strength assessment in youth athletes, progressions to academic literature has demonstrated assessment of these characteristics as safe and beneficial for long-term athlete development (LTAD) (Ford *et al.*, 2011; Lloyd & Oliver, 2012; McMaster *et al.*, 2014).

2.3.2.2 Evaluating power characteristics of soccer

Alongside the importance of maximal strength characteristics, an ability to perform rapid and forceful movements are also essential within soccer match play. Whilst many researchers suggest power characteristics to be underpinned by strength qualities, it is argued that

'power' is an individual physical characteristic (Cronin & Sleivert, 2005). Assessment of power is more commonly applied in practical settings compared with that of strength (Paul & Nassis, 2015b). Power characteristics are commonly exhibited during jumps, explosive changes in direction or velocity, and shooting/passing actions during soccer training and match play (Di Salvo *et al.*, 2009; Faude *et al.*, 2012; Stølen *et al.*, 2005). Consequently, tests that allow for analysis and interpretation of power characteristics relevant to these movements and actions are commonly implemented within soccer clubs. Countermovement vertical jump (CMJ), in particular, is one of the most featured tests used within testing and monitoring practices of soccer clubs, likely due to its prevalence during a game (Iacono *et al.*, 2017; Paul & Nassis, 2015b; Stølen *et al.*, 2005). Furthermore, the ability to quickly and easily assess this capacity with a low-cost to fatigue, makes regular testing easier to sanction within busy training schedules comparative to other assessments (McMaster *et al.*, 2014). Although less common than the evaluation of CMJ ability, the use of standing broad jump (SBJ) assessments have been consistently implemented within physical fitness testing batteries of soccer players (Deprez, Valente-Dos-Santos, *et al.*, 2015). Similar to CMJ, the SBJ assesses the power characteristics of the lower limbs in an explosive, ballistic, whole body movement. Assessment of the SBJ may be adopted by practitioners with limited access to equipment or facilities, as it only requires an open reel tape measure. However, landing requirements of the SBJ place greater emphases on motor coordination and competence (Fransen *et al.*, 2014). Assessments challenging the motor coordination of youth and child athletes have been suggested to demonstrate discriminative ability between varied performance standards (Deprez, Valente-Dos-Santos, *et al.*, 2015; Fransen *et al.*, 2014, 2017), thus promoting the implementation of SBJ as an additional or alternative to CMJ to assess power characteristics within an athletic population. Additional, less common assessments of power within soccer

players have included rate of force development (RFD) assessments using isometric dynamometers (Dos'Santos *et al.*, 2017a; Requena *et al.*, 2009), isolated examination of COD ability (Loturco *et al.*, 2019), or alternative jumping or throwing tests (Chamari *et al.*, 2008; Hulse *et al.*, 2013; Van Den Tillaar & Marques, 2013). As a key influencer of assessment choice is an ability to compare to normative scoring from varied population groups, these less commonly implemented measures often fall wayward to CMJ when assembling a testing battery to assess physical characteristics of soccer players (Turner *et al.*, 2011).

Similar to strength, stability of power characteristics during the formative years has been questioned within the literature (Lloyd & Oliver, 2012), likely due to improvements in muscular power being attributed to maturational influences alongside the underpinning strength qualities associated with power actions. For example, Murtagh *et al.* (2018) suggest that horizontal/vertical jump measures only discriminate between elite vs. control youth soccer players at mid- and post-PHV, questioning suitability of such measures in a younger, less mature sample. This being said, the adolescent years provide an opportunity to train and develop both movement qualities, and strength/power ability (Lloyd *et al.*, 2013; Lloyd & Oliver, 2012; Malina *et al.*, 2015). For example, Otero-Esquina *et al.* (2017) suggest that a higher strength/power training frequency improving various attributes in elite youth soccer players, specifically power-based actions (such as changes in direction and jumping). As a result, engaging in regular and appropriate training may assist with development of these characteristics. Due to prerequisites of movement skills and competency required by some power assessments, appropriateness of these tests to accurately and reliably assess power characteristics, specifically within a youth sample, has been questioned (Fransen *et al.*, 2012; Vandendriessche *et al.*, 2012). Consequently, to obtain accurate and representative

observations of power characteristics within physically immature and inexperienced samples, simplistic and familiar tasks should be adopted (Murtagh *et al.*, 2018).

When assessing characteristics of power, it has been proposed that the test should provide appropriate information on the skill that it intends to assess. For example, when assessing CMJ performance, some researchers suggest that reporting jump height alone provides insufficient information regarding the neuromuscular status of the lower limbs (Claudino *et al.*, 2017). This premise is supported by work from Nimphius *et al.* (2018, 2016) who suggest that analysis of total time taken to complete COD tests provides insufficient information on COD performance. Moreover, it has also been debated whether the use of best or average values when assessing measures of power (eg. CMJ) is most appropriate (Al Haddad *et al.*, 2015). This being said, it has been suggested that jump height alone may provide appropriate information for the assessment and monitoring of power characteristics in an athletic population (Claudino *et al.*, 2017), and, that analysis of either best or average values provide similar information (Al Haddad *et al.*, 2015).

Finally, the relevance of power to soccer gameplay and performance have been questioned by some researchers. For example, some research has shown differences between performance standards for CMJ performance (Aquino *et al.*, 2017; Gissis *et al.*, 2006), whereas others observe no differences between varied performance levels (Malina *et al.*, 2007; Martinez-Santos, Castillo, & Los Arcos, 2016). However, these relationships are to be considered simplistic and not causal (Paul & Nassis, 2015b). Regardless, substantial evidence exists suggesting power to be a fundamental physical characteristic relevant to generic actions exhibited during soccer gameplay (Deprez, Valente-Dos-Santos, *et al.*, 2015),

therefore, warrants appropriate and dedicated assessment during the testing and monitoring process.

2.3.3 Evaluating anthropometric and morphologic characteristics of soccer

Regular monitoring of anthropometric and morphologic characteristics is a staple process within daily operations within a professional soccer club environment. Accurate measures of body mass and body composition provide valuable information throughout the season for senior level soccer players (Suarez-Arrones *et al.*, 2018), whereas assessment of stature and predictions of growth rate are commonplace within junior academy soccer (Carling *et al.*, 2012; Malina *et al.*, 2017, 2015). Whilst several gold-standard measurement techniques for anthropometric and morphologic characteristics are proposed within the literature, the ability of practitioners to gain access to the required equipment and techniques is often limited (Suarez-Arrones *et al.*, 2018). Consequently, many studies adopt simplistic and non-invasive methods requiring readily available and low-cost equipment when taking these measures.

When assessing body mass in the use of digital floor scales is adopted almost exclusively (ACSM, 2006). Despite alternative assessment methodologies for body mass available such as dual-energy X-ray absorptiometry (DXA), underwater weighing, and air-displacement plethysmography, these methods are commonly only implemented for accurate measures of body composition. However, despite the high accuracy and reliability of these methods (Colyer *et al.*, 2016), access to the equipment required to conduct these tests within soccer populations is often limited to medical facilities and select elite clubs (Suarez-Arrones *et al.*, 2018). Moreover, alongside equipment and resources, these methods are often extremely consuming on time, requiring lengthy data capture processes often allowing for analysis of

only one individual at a time. As a result, the use of digital floor scales has been predominantly used in research and practice to measure body mass of soccer athletes. Digital floor scales have reported appropriate accuracy for measurement of body mass across varied populations (Yorkin *et al.*, 2013). Similarly, many digital floor scales report weights to the nearest 100g, providing sufficient detail to report meaningful changes in body mass within athletic populations (Colyer *et al.*, 2016).

Body composition assessment may also provide useful information regarding body fat percentage, lean muscle mass, and bone density within athletic populations. Whilst DXA scanning again is viewed as a gold-standard measure for providing accurate information regarding body composition (Suarez-Arrones *et al.*, 2018), as long as hydration is controlled for, similar to the reasons stated above, the use of additional, more accessible methods are regularly implemented within an applied sports setting. Bioelectrical impedance analysis and skinfolds are amongst the most common assessments of body composition within soccer players, allowing for estimates of adiposity to be made regularly around training and competition (Ostojic, 2006). Nearly perfect relationships ($r = 0.96$) between bioelectrical impedance analysis and skinfolds have been reported in the literature (Ostojic, 2006). However, skinfold thickness is commonly assessed to predict body fat in soccer players, demonstrating good relationships comparative to DXA ($r = 0.88$) (Reilly *et al.*, 2009).

When assessing stature in athletic populations, the use of free-standing stadiometers is adopted almost exclusively. Whilst it is appreciated that standing stature reaches a plateau following adolescence (~18 years) (Baxter-Jones, 1995), as discussed during **Section 2.2.1.3**, anthropometric and morphologic profiling of senior soccer players may influence positional allocation or perceived suitability to play a given position (Bloomfield *et al.*, 2007; Sutton *et*

al., 2009). However, due to the vast and varying rates of growth and physical development experienced across childhood and adolescence (Carling *et al.*, 2012; Mirwald *et al.*, 2002), assessment of stature is substantially more prevalent and constructive within youth populations. The implementation of varied measures of length/stature have been promoted to monitor rates of growth and maturation using low-cost equipment and in a non-invasive manner (Malina *et al.*, 2015), thus proving widely accessible for researchers and practitioners. The most common method of assessment when predicting rates of growth and maturation is derived from a range of anthropometric measurements, including sitting height (Mirwald *et al.*, 2002). The “Mirwald equation”, proposed by Mirwald *et al.* (2002), is a gender-specific regression equation proposed as a reliable, non-invasive, and practical method for the measure of biological maturity in adolescent athletes. The “Mirwald equation” provides an estimate of ‘maturity offset’, typically defined as an estimation of the number of years an individual is from their peak height velocity (PHV). This in turn can be subtracted from the individual’s chronological age to predict their age at peak height velocity (APHV) (Mirwald *et al.*, 2002). This is useful information for coaches and practitioners, as it provides additional information regarding rate and stage of maturation, in addition to chronological age. As a result, this method has been used widely within research on adolescent soccer players (Lloyd *et al.*, 2014; Pearson, Naughton, & Torode, 2006; Towlson *et al.*, 2017), attempting to capture predicted maturity status to inform training and decision making during the formative years. More recently, researchers have attempted to progress the accuracy of this non-invasive and popular method (Koziet & Malina, 2018; Moore *et al.*, 2015), however researchers and practitioners continue to implement the “Mirwald equation” when estimating maturity status in adolescent soccer athletes (Borges *et al.*, 2018; Doncaster, Iga, *et al.*, 2018; Müller *et al.*, 2018; Murtagh *et al.*, 2018; Wright & Chesterton, 2018). Despite this, it should be

acknowledged that these equations to estimate maturity status (such as the “Mirwald” equation) may be subject to error, as they are indeed “predictive” and not direct measures of maturity status. These predictive equations are reported to perform best nearer to the observed measure (eg. closest to the actual time of APHV), therefore, substantial error (in excess of ± 1 year) in prediction may occur in individuals earlier or later in their somatic growth periods.

The varying rates of physical and biological maturation has proven implications on TI and selection/deselection processes, as discussed previously in **Section 2.1.3.2**. It is appreciated that estimations of maturity status are predictive, and open to some error and inaccuracy within their calculations. However, the variance in biological and physical development, particularly in boys between 13-15 years is evident (Malina *et al.*, 2015). Therefore, measurement of this characteristic within the testing and monitoring process is crucial for representative evaluation of anthropometric and morphologic characteristics within a sample of youth athletes.

2.3.4 Physical performance testing in soccer – summary

- Field-based assessments are popular, and more ecologically valid, practical alternatives to traditional lab-based assessments.
- The YYIRT L1 appears not to be influenced by physical maturity status, both regarding within-age group performance (Deprez, Valente-dos-Santos, *et al.*, 2014; Doncaster, Iga, *et al.*, 2018), and test-retest reliability (Deprez, Coutts, *et al.*, 2014).
- GPS metrics lack sensitivity to provide appropriate and accurate feedback on linear and multi-directional sprint performance (Akenhead *et al.*, 2014; Buchheit *et al.*, 2014), thus individual tests are warranted to assess this ability.

- Due to high potential error during sprint/COD/agility assessment, several methodological considerations should be acknowledged (Haugen & Buchheit, 2016).
- The unfamiliarity and complexity of COD and agility tasks may result in higher variability of test performance in inexperienced youth populations.
- Whilst strength evaluations are safe and provide important information regarding a physical characteristic relevant to soccer performance, the complexity and associated fatigue of dynamic strength assessments may influence practitioners to seek alternative means of assessment for this characteristic.
- Evaluation of jump performance appears a popular method to assess lower body power within soccer athletes. However, assessment of this ability may be influenced by maturity status (Murtagh *et al.*, 2018).
- Resultant of the vast growth and maturation developments across adolescence, assessment of standing stature, body mass, and a non-invasive predictive measure of maturity status may provide meaningful information regarding youth soccer players.

2.4 Physical performance testing for talent identification and development

To conclude this literature review, the relevance of physical performance testing within TI and TD processes will be briefly discussed. Whilst it has been reiterated throughout this thesis that potential predictors of talent for soccer are multi-disciplinary in nature (**Section 2.1**), the importance of progression within individual disciplines alongside developments in physical demands of soccer at professional and youth level have also been established (**Section 2.2**). Consequently, the value of physical fitness testing towards the identification and development of youth soccer players should be acknowledged.

2.4.1 Physical performance testing for talent identification

Several previous studies have investigated the discriminative value of physical fitness testing for TI purposes adopting both cross-sectional (**Table 2.1**) and longitudinal (**Table 2.2**) designs. Although cross-sectional designs have been scrutinised in their ability to provide valuable information relative to TI (due to players not yet achieving senior professional status), they provide data regarding observed discrepancies between distinct performance standards on a range of physical measures (Coelho E Silva *et al.*, 2010; Forsman *et al.*, 2016; Hulse *et al.*, 2013; Reilly *et al.*, 2000). Despite this, observed differences have varied substantially across studies, leading to uncertainty around discriminative value of these measures (**Table 2.1**). Similarly, many studies compare limited age groups (often senior academy players \geq U16) and disparate playing standards (professional vs. control). Considering professional soccer academies recruit and develop players from early childhood (Hulse *et al.*, 2013), and, the multiple tiers within governing body soccer (Mujika, Santisteban, *et al.*, 2009), understanding of performance differences across all age groups and performance standards would provide valuable information when adopting a cross-sectional study design. Similarly, to improve

representation of data of a population, large and comprehensive samples should be recruited, a limitation of several previous studies of this nature (Aquino *et al.*, 2017; Gouvêa *et al.*, 2017; Reilly *et al.*, 2000; Waldron & Murphy, 2016). Finally, given the multi-dimensional nature of soccer and varying demands placed upon players during training and competition (**Section 2.2**), a comprehensive range of physical characteristics should be assessed; again, a limitation of several previous studies (Aquino *et al.*, 2017; Gouvêa *et al.*, 2017; Malina *et al.*, 2007; Mirkov *et al.*, 2015).

Longitudinal study designs have been advocated in the literature, providing representative information on successful vs. unsuccessful player groups transitioning to senior professional soccer (Sarmiento, Anguera, *et al.*, 2018; Unnithan *et al.*, 2012; Williams & Reilly, 2000). Whilst a small number of studies have succeeded in collating data from a comprehensive range of measures and age groups (Deprez, Fransen, *et al.*, 2015; Gonaus & Müller, 2012), many studies, again, demonstrate similar limitations to those reported in cross-sectional studies (limited age groups: Gil *et al.*, 2014; Gravina *et al.*, 2008; le Gall *et al.*, 2010, low sample size: Figueiredo *et al.*, 2009; Gil *et al.*, 2014; Gravina *et al.*, 2008, and, limited testing batteries: Emmonds *et al.*, 2016; Huijgen *et al.*, 2014). Additionally, prognostic relevance of potential predictors range substantially across-studies (**Table 2.2**). Considering the perceived importance of early recruitment and specialisation relative to success, limited information regarding young academy players or age of recruitment relative to physical development and subsequent success exist. Progression of the above limitations would assist coaches and practitioners in making more educated and informed decisions regarding physical fitness testing as part of TI.

Table 2.1 Empirical evidence of the cross-sectional relevance of physiological and physical assessments to TI in youth soccer.

Dimensions of assessment					Physiology					Physique		
					Endurance	Speed			Neuromuscular		Anthropometry	
Assessment					Endurance	Sprint (≤20m)	Sprint (>20m)	COD	Power	Strength	Height	Weight
Number of studies					9	5	9	8	12	1	12	12
Number of tested effect sizes					12	5	12	11	15	4	15	15
Percentage of sig. effect sizes					83.0	80.0	83.0	63.6	73.3	100.0	40.0	46.7
Median (<i>d</i>)					1.05	0.66	0.84	0.55	0.68	0.88	0.33	0.30
Study	Sample	PL 1	PL 2	Age group	ES (<i>d</i>)							
Aquino et al. (2017)	66	Local	Elite	U16	0.31		2.02*		0.68*		0.58*	0.58*
Carling et al. (2012)	158	Non-PRO	PRO	U14	0.32	0.00	0.04		0.49		0.33	0.30
Coelho e Silva et al. (2010)	128	Local	Elite	U13-U14	1.37*		0.88*	-0.24	0.86*		1.12*	1.08*
Forsman et al. (2016)	114	Sub-elite	Elite	U16	0.61*		0.76*	1.02*	0.30		0.39	0.47*
Gouvêa et al. (2017)	62	Low skill	High skill	U11-U17	1.40*				1.10*		1.14*	0.78*
Hulse et al. (2013)	77	Average	Above average	U9-U18		0.69*		0.36*	0.99*		0.54*	0.45*
Malina et al. (2007)	69	Lowest skill	Highest skill	U13-U15	1.29*		0.86*		0.68*		0.29	0.21
Mirkov et al. (2010)	89	Control	National	U11-U14				2.34*	1.02*		0.09	0.10
Rebelo et al. (2013)	180	Non-elite	Elite	U19	1.00*	0.66*	0.50*	0.86*	0.64*		0.59*	0.60*
Reilly et al. (2000)	31	Sub-elite	Elite	U16	1.19*	1.22*	0.84*	3.29*	0.83*		-0.72*	-1.70*
Vaeyens et al. (2006)	78	Non-elite	Elite	U13	0.59*		1.50*	0.61*	0.64*	0.65*	-0.24	-0.09
	79			U14	0.84*		0.78*	0.47	0.50	0.70*	-0.33	-0.31
	69			U15	1.11*		1.18*	0.48	0.86*	1.16*	-0.10	-0.11
	53			U16	1.09*		0.50	0.42	0.63*	1.05*	-0.44	-0.29
Waldron & Murphy (2016)	31	Sub-elite	Elite	U14		2.53*	5.06*	1.24*	0.09		0.26	0.22

PL 1: performance level 1; PL 2: performance level 2; Non-PRO: non-professional; PRO: professional; ES: effect size (Cohen's *d*); **p*<0.05.

Table 2.2 Empirical evidence of the prognostic relevance of physiological and physical predictors to TI in youth soccer (adapted from Murr, Raabe & Höner et al., 2018).

Dimensions of predictor						Physiology					Physique		
						Endurance		Speed			Neuromuscular		Anthropometry
Predictor						Endurance	Sprint (≤20m)	Sprint (>20m)	COD	Power	Strength	Height	Weight
Number of studies						9	5	7	7	7	3	7	7
Number of tested effect sizes						25	18	21	21	23	5	20	20
Percentage of sig. effect sizes						52.0	44.4	57.1	61.9	26.1	0.0	25.0	20.0
Median (<i>d</i>)						0.47	0.41	0.59	0.42	0.31	0.14	0.29	0.23
Study	Sample	PL T1	PL T2	PP	Age group	ES (<i>d</i>)							
Deprez et al. (2015a)	147	Elite	NEXT	2 years	U10	0.47	0.43*	0.59*	0.15	0.24		0.04	-0.36*
	132	Belgian		2 years	U11	0.64	0.44*	0.32	0.81*	0.32		0.13	-0.14
	112			2 years	U12	0.66*	0.17	0.62*	0.5	0.47		0.11	-0.06
	102			2 years	U13	0.48*	0.35	0.56*	-0.14	0.53		-0.08	0.14
	108			2 years	U14	0.81*	0.64*	1.04*	0.25	0.98*		0.31	0.51*
	97			2 years	U15	0.82*	1.00*	1.07*	0.40	1.09*		0.50*	0.59*
	87			2 years	U16	0.36	0.15	0.58*	0.17	0.18		0.33	0.24
	79			2 years	U17	0.85*	0.15	0.48	0.71*	0.00		0.36	0.26
Emmonds et al. (2016)	149	Elite	PRO	6 years	U12								
	170	English		5 years	U13								
	144			4 years	U14								
	151			3 years	U15								
	123			2 years	U16		0.70*	0.37*					
	269			1 year	U18	0.72*	1.09*	1.26*					
Figueiredo et al. (2009)	33	Regional	NEXT	2 years	U12/U13	1.56*		1.05*	1.02*	0.70		1.03*	0.41
	36	Portugal		2 years	U14/U15	0.72*		1.04*	1.71*	1.07*		1.72*	1.23*
Gil, Ruiz et al. (2007)	48	Regional	NEXT	<1 year	U15	0.68*		0.88*	0.42*	0.13		0.81*	0.43
	53	Spain		<1 year	U16	0.08		0.06	0.55*	-0.51		-0.22	0.31
	41			<1 year	U17	-0.24		0.10	0.87*	0.38		0.28	0.22
	52			<1 year	U18	0.41		0.08	0.13	-0.13		0.11	0.02

PL T1: performance level time 1; PL T2: performance level time 2; NEXT: next age class at the competitive playing level; NT: joined a national team; PRO: turned professional; FTP: became a first-team regular player; PP: prognostic period; ES: effect size (Cohen's *d*); **p*<0.05.

Table 2.2 Cont.

Dimensions of predictor						Physiology						Physique	
						Endurance		Speed			Neuromuscular		Anthropometry
Predictor						Endurance	Sprint (<20m)	Sprint (>20m)	COD	Power	Strength	Height	Weight
Number of studies						9	5	7	7	7	3	7	7
Number of tested effect sizes						25	18	21	21	23	5	20	20
Percentage of sig. effect sizes						52.0	44.4	57.1	61.9	26.1	0.0	25.0	20.0
Median (<i>d</i>)						0.47	0.41	0.59	0.42	0.31	0.14	0.29	0.23
Study	Sample	PL T1	PL T2	PP	Age group	ES (<i>d</i>)							
Gil et al. (2014)	85	Elite Spain	NEXT	1 year	U10/U11	0.67*	0.49	0.48	0.67*	0.06	0.58	-0.18	0.13
Gonaus & Müller (2012)	410	Elite Australia	NT	3 years	U15	0.28*	0.28*		0.49*	0.31*			
	504			2 years	U16	0.27*	0.15		0.39*	0.42*			
	456			1 year	U17	0.28*	0.46*		0.32*	0.28*			
	272			1 year	U18	0.09	0.50		0.36*	0.21			
Gravina et al. (2008)	66	Elite Spain	FTP	<1 year	U11-U14	-0.11		1.39*	0.78*	0.00	0.14	0.27	0.29
Huijgen et al. (2014)	113	Elite Holland	NEXT	1 year	U16-U19	0.07			0.41			-0.14	0.07
Le Gall et al. (2010)	105	Elite France	PRO	6 years	U14	0.49	0.00	0.11		0.18	-0.05	0.34	0.18
	92			5 years	U15	0.38	0.28	0.64		0.51	0.25	0.29	0.05
	86			4 years	U16	0.20	0.39	0.59		0.54	-0.45	0.87*	0.71

PL T1: performance level time 1; PL T2: performance level time 2; NEXT: next age class at the competitive playing level; NT: joined a national team; PRO: turned professional; FTP: became a first-team regular player; PP: prognostic period; ES: effect size (Cohen's *d*); **p*<0.05.

2.4.2 Physical performance testing for talent development

Ability to effectively develop talented soccer players relies upon accurate selection, administration, and interpretation of measures that inform training processes. Whilst **Section 2.2** of this literature review discussed physical characteristics of relevance to both professional and youth soccer performance, **Section 2.3** discussed a range of considerations when administering these tests, specifically within a developing child/adolescent sample. Vast physiological and biological changes occurring across adolescence may influence the accuracy and stability of measures, specifically those requiring high physical competency or prerequisites of strength (Ford *et al.*, 2011; Lloyd & Oliver, 2012; Vandendriessche *et al.*, 2012; Vandompe *et al.*, 2012). Moreover, considering that knowledge gaps remain regarding validity of commonly-used physical measures to assess entire age ranges and performance standards, further study is required to inform upon the ability of these tests to provide representative and accurate information.

Considering the historic nature of TI (subjective scouting systems), combined with the ongoing influence of coach opinion within the TI and TD process, it is important that identified characteristics and measures align with distinguishable differences in observed soccer performance and link directly to the game model of the club. Therefore, if appropriate measures are identified, performance on these measures should align with coaches' opinions. Despite this premise, limited research is available regarding the alignment of commonly implemented measures for physical performance development in soccer, and subjective coach opinion. Development within this knowledge gap would assist in shaping appropriate and representative testing batteries reflective of observed performance, alongside providing information on characteristics most accurately identified during soccer performance.

2.5 Literature review – summary

This literature review described the current evidence available on the use of physical fitness testing as a suitable tool to assess youth soccer athletes, and the potential application of physical fitness testing within TI and TD processes. Throughout the literature review, a background of TI and TD was provided (**Section 2.1**), an overview of the physical characteristics prevalent in both professional and youth soccer were discussed (**Section 2.2**), a thorough discussion of means of assessment for the characteristics identified within Section 2.2 was made (**Section 2.3**), and, the value of physical performance tests for TI and TD purposes was critically discussed. Whilst previous literature has addressed the ability of physical fitness tests to discriminate between differing performance standards of youth soccer players, adopting both cross-sectional (**Table 2.1**), and longitudinal (**Table 2.2**) approaches, several gaps in the literature are identified:

- Ability of physical fitness tests to differentiate and discriminate between varied performance standards of youth soccer players, both acutely, and longitudinally, remain inconclusive.
- Given the vast biological and physiological changes that occur across adolescence, and discrepancies in demands between youth-senior soccer, further research is required to validate appropriate measures across more comprehensive age ranges.
- Given the multi-disciplinary nature of TI and TD, understanding of the relevance and usefulness of physical fitness testing, within these processes, would provide useful information.

The following chapters and the studies within these chapters are designed to address these key gaps in the literature.

2.6 Aims

As introduced in Chapter 1 of this thesis, the general purpose of this thesis is to better understand how physical fitness testing may be used to contribute towards the TI and TD process of youth soccer players, and how valid physical fitness testing methods may be when being implemented within various samples of youth soccer players. Following key gaps in the current evidence available, highlighted in this literature review chapter, the following specific aims of this thesis are defined:

1. To examine the cross-sectional and longitudinal ability of a comprehensive physical fitness testing battery to discriminate between ecologically valid and varying abilities of youth soccer players, across a range of ages.
2. To assess quality of measures used to assess physical characteristics of youth soccer players across the full age spectrum captured within a youth soccer academy.
3. To examine the extent to which physical fitness test performance aligns with coach perception of ability and rating, thus informing decision making relative to TI.
4. To examine the ability of physical fitness testing to provide valuable information relative to soccer performance and success in youth soccer players.

VII – SYNTHESIS (LITERATURE REVIEW – CHAPTER 3)

Following a review of the literature review, it is apparent that avenues for future research exist regarding the use of physical fitness testing in youth soccer players with regards to TI & TD. Whilst many previous studies address the discriminative ability of physical fitness tests in a cross-sectional manner, limitations of these studies (as discussed in **Section 2.4**) deny a representative overview of this process to discriminate between performance standards, informing TI.

The first experimental chapter of this thesis aims to explore the cross-sectional discriminative ability of physical fitness tests to differentiate between varied performance standards. Similarly, this chapter also aims to assess the quality of physical fitness test measures to provide representative and reliable results across a broad age range of youth soccer players.

This first chapter will consult a national governing body, and align closely with specifications regarding differentiation of playing standards and age ranges, and adopt a broad range of physical fitness test measures associated with soccer performance proposed by previous research.

Findings of this first experimental chapter will inform subsequent experimental chapters with regards to areas for future research around the discriminative ability, methodological issues, and validity of physical fitness tests within the TI & TD process.

CHAPTER 3

RELIABILITY AND VALIDITY OF COMMONLY USED FIELD-BASED FITNESS TESTS IN YOUTH SOCCER PLAYERS

Dugdale, J.H., Arthur, C.A., Sanders, D., & Hunter, A.M. (2019) Reliability and validity of field-based fitness tests in youth soccer players. *European Journal of Sport Science*, 19(6), 745-756.

<https://doi.org/10.1080/17461391.2018.1556739>

Abstract

This study aimed to establish between-day reliability and validity of commonly used field-based fitness tests in youth soccer players of varied age and playing standards, and to discriminate between players without (“unidentified”) or with (“identified”) a direct route to professional football through their existing club pathway. Three-hundred-and-seventy-three Scottish youth soccer players (U11–U17) from 3 different playing standards (amateur, development, performance) completed a battery of commonly used generic field-based fitness tests (grip dynamometry, standing broad jump, countermovement vertical jump, 505 (505COD) and T-Drill (T-Test) change of direction, and 10/20m sprint tests) on two separate occasions within 7–14 days. The majority of field-based fitness tests selected within this study proved to be reliable measures of physical performance (ICC = 0.83-0.97; $p < 0.01$). However, COD tests showed weaker reliability in younger participants (ICC = 0.57-0.79; $p < 0.01$). The field-based fitness testing battery discriminated between the unidentified and identified players; $\chi^2 (7) = 101.646$, $p < 0.01$, with 70.2% of players being correctly classified. Findings of the present study have shown field-based fitness tests to be reliable measures of physical performance in youth soccer players. However, results from the 505COD and T-Test change of direction tests may be more variable in younger players, potentially due to complex demands of these tests and the limited training age established by these players. Whilst the testing battery selected in this study was able to discriminate between unidentified and identified players, findings were inconsistent when attempting to differentiate between individual playing standards within the “identified” player group (development vs. performance).

3.1 Introduction

As discussed extensively during **Section 2.2**, soccer is an intermittent, high intensity sport requiring a broad range of physical abilities in order to achieve competitive success. Given the global popularity of competitive soccer and its vast participation levels at grass-roots, there has been a rapid increase in the interest and importance placed on an ability to examine and differentiate between varied competitive standards of youth soccer players (Unnithan *et al.*, 2012). Whilst governing bodies adopt multiple approaches in categorising performance standards specific to their varied infrastructures, it is commonly accepted that the selection/deselection or talent identification process relies on players being signed to a professional soccer academy (identified) comparative to those are not (unidentified) (Unnithan *et al.*, 2012; Murr, Raabe, & Höner, 2018). As introduced in **Section 2.1**, selection/deselection within youth soccer historically employed scouting systems reliant on individual opinion and philosophy (Reilly *et al.*, 2000; Unnithan *et al.*, 2012). However, in recent years this process has been scrutinised due to its subjective nature and potential bias with calls for a more scientific approach (Larkin & O'Connor, 2017; O'Connor, Larkin, & Williams, 2016). Whilst many researchers discuss the multi-dimensional and complex nature associated with assessing ability within youth soccer (Larkin & O'Connor, 2017; Reeves, Roberts *et al.*, 2018; Sarmiento, Anguera, *et al.*, 2018), including measures of physical fitness as a component of assessment and talent identification processes remains prevalent within current selection/deselection processes (Gil *et al.*, 2014; Gonaus & Müller, 2012; Huijgen *et al.*, 2014; Murr, Raabe, & Höner, 2018).

As discussed within **Section 2.3**, field-based fitness tests have been widely utilised by practitioners to assess and monitor performance characteristics in soccer players. Field-based

fitness tests allow for assessing multiple individuals simultaneously, generally requiring low cost equipment and easy accessibility for practitioners and researchers (Hulse *et al.*, 2013; Paul & Nassis, 2015a; Pyne, Spencer, & Mujika, 2014). Additionally, a comprehensive field-based testing battery relevant to the multiple physical demands of soccer can generally be conducted within a single session (Hulse *et al.*, 2013; Pyne *et al.*, 2014; Vescovi *et al.*, 2011), therefore proving extremely time effective and practical amongst practitioners. As evidenced within **Section 2.3** of this thesis, assessments of aerobic fitness, repeated sprint ability, change of direction, and linear sprinting have typically been carried out when assessing youth soccer players. However, due to physical advancements present within modern-day competitive soccer (**Section 2.2**), attributes of explosive power and muscular strength are receiving substantial interest within recent research.

A plethora of research has been conducted on the suitability and application of field-based fitness tests to the sport of soccer, however reliability and validity of these measures are mainly demonstrated in senior athletes (Paul & Nassis, 2015a). Studies attempting to examine reliability and validity of field-based fitness tests in youth soccer samples have either used limited testing batteries (Rebelo *et al.*, 2013; Thomas, *et al.*, 2009), demonstrated ability to discriminate between players of the same competitive standard (Hulse *et al.*, 2013), or evaluated test reliability for restricted age ranges (Rebelo *et al.*, 2013; Thomas *et al.*, 2009). One of the attractions of a valid fitness testing battery is the potential ability to discriminate between various performance standards (Murr, Raabe, *et al.*, 2018), however this is still to be conclusively established within a youth sample. Prior research examining performance characteristics of youth soccer players has focussed on senior academy players (U16-U19) (le Gall *et al.*, 2010; Mujika, Santisteban *et al.*, 2009), yet many professional soccer academies register players as young as U9 (Hulse *et al.*, 2013). Due to the influence of physical

competency and relative training age on reliability of performance testing (Vandorpe *et al.*, 2012; Vandendriessche *et al.*, 2012), it is important that performance tests are validated across the entire age spectrum they intend to assess. Additionally, increased exposure to training and greater training volume experienced by players of a higher competitive playing level may also influence consistency of testing performance (Rebelo *et al.*, 2013). As a result, it is hypothesised that field-based tests for youth soccer players will be, mostly, valid and reliable, although more variable than previously reported in adults. Therefore, the purpose of this study was to: i) examine the between-day reliability of commonly used field-based fitness tests across an appropriate age range (U11-U17) and across multiple performance standards (amateur, development, performance) included within a national governing body for soccer; ii) to assess the construct validity of the testing battery to discriminate between multiple age groups (U11-U17); and iii) evaluate the ability of a battery of commonly used field-based fitness tests to discriminate between playing standards (amateur, development, performance) included within a national governing body for soccer and to discriminate between “unidentified” (amateur) and “identified” (within a progressive pathway to professional soccer) youth soccer players.

3.2 Methods

Participants:

Three-hundred-and-seventy-three Scottish youth soccer players (mean \pm SD: age 13.5 ± 1.8 years; stature 161.1 ± 13.3 cm; body mass: 50.8 ± 12.4 kg) from the 3 different playing standards (amateur, development, performance) and 7 age groups (U11, U12, U13, U14, U15, U16, & U17) identified by the “Club Academy Scotland” (CAS) structure of the Scottish Football Association (SFA) volunteered to participate in this study (**Figure 3.1**). Participants were categorised as either “unidentified” (amateur level players – no direct route to professional football), or “identified” (development/performance level players – direct route to professional football through existing club pathway). Additionally, participants were categorised as “amateur” (recreational players), “development” (lower ranked professional academies), and “performance” (“elite” level academies) based upon the SFA CAS structure. Due to the vast positional demands of goalkeepers within soccer, players of this position were excluded from analysis. Prior to conducting any trials, participant and parental/guardian consent was gained alongside providing comprehensive written and oral explanations about the study. Institutional ethical approval was granted.

Design:

Participants completed 2 testing sessions ~1.5 hours in length separated by a washout period of 7–14 days. Data were collected from 7 field-based fitness tests commonly used as physical performance measures within youth soccer (Paul & Nassis, 2015a). All selected tests were identified to be appropriate for implementation across the entire age range of the selected sample, and relevant to the demands of soccer (Paul & Nassis, 2015a). To account for circadian variability (Drust *et al.*, 2005), both testing sessions took place at the same time of

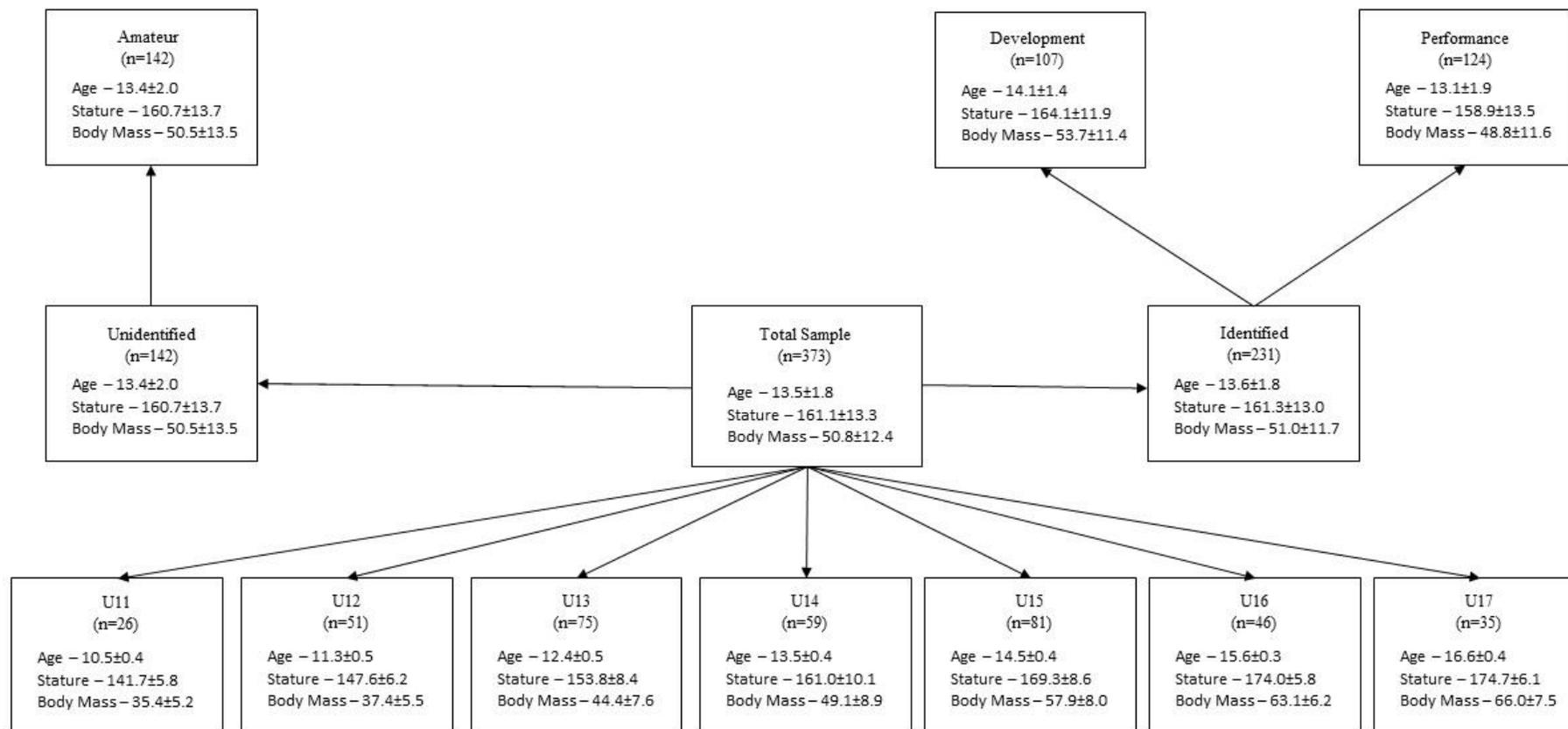


Figure 3.1 Sample breakdown and participant descriptives for age groups, identification status, and playing standard. Age (years); Stature (cm); Body mass (kg). Data are presented as mean ± SD.

day and during players' normal training hours. Testing sessions were completed a minimum of 48 hours following a competitive game, and in absence of strenuous exercise within 24 hours prior. Testing sessions were conducted indoors (~22°C) on a non-slip sports hall playing surface. Upon arrival for the initial testing session, participants provided basic descriptive details via a self-report questionnaire including: date of birth, associated playing club, main playing position, and the number of club training sessions completed/week. Anthropometric measures were taken during testing session 1 only. Prior to both testing sessions, all participants conducted a standardised warm-up protocol consisting of light aerobic activity, dynamic stretching, and progressive sprinting. Testing order and procedures for each test was the same on each occasion. The research team remained constant throughout the data collection process with the same researchers collecting data from the same fitness tests consistently across sessions.

Procedures:

Following the standardised warm-up, participants received verbal instruction and demonstrations from the research team immediately prior to conducting 2-3 familiarisation attempts for each test. When required, guidance and feedback were provided to participants by the research team following each familiarisation attempt, however no guidance was provided to participants between recorded attempts. For tests where electronic timing gates were used, gates were adjusted to an appropriate height as per the mean stature of the sample group, and start positions were standardised as a fixed-position crouch start from 1m behind the start gate (Haugen & Buchheit, 2016). Data were collected using the Brower TC Timing System (Brower Timing Systems, Draper, UT) with total time reported to the nearest 0.01s. Participants completed 3 attempts of each test (unless otherwise stated) with the best

attempt being selected for analysis. Recovery intervals between attempts were standardised at 3minutes for each test.

Anthropometrics

Standing stature was assessed using a free-standing stadiometer (Seca, Birmingham, UK) and reported to the nearest 0.1cm. Body mass was assessed using digital floor scales (Seca, Birmingham, UK) and reported to the nearest 0.1kg.

Grip Dynamometry (Grip Strength)

Grip strength was selected as a suitable strength evaluation for implementation across the entire sample within this study (U11–U17) and was examined using an analogue dynamometer (Takei 5001, Takei Scientific Instruments Co., Niigata-City, Japan). Attempts were collected from participants' dominant hand (specified as the participants' writing hand), and with the appropriate hand spacing adjusted for each individual as per manufacturer guidelines. Participants were instructed to hold the dynamometer above head with a locked arm. Participants applied maximum pressure by squeezing the handle of the dynamometer. Over a 5-second period, the dynamometer was lowered in an arc towards the participant's hip maintaining a locked arm. Data were recorded to the nearest 0.5kg.

Standing Broad Jump (SBJ)

SBJ was examined using an open reel tape measure (PerformBetter, Southam, UK) secured to the ground. Participants were instructed to place the front edge of their footwear as close to, but not touching, a designated start line. Without repositioning their feet and utilising countermovement and arm swing, participants jumped forwards maximally landing on both feet. Attempts were disqualified if participants moved their feet upon take-off or landing, or

if additional body parts (other than the feet) came in contact with the ground. Measurements were taken from the furthest edge of the designated start line, to the back of the rear landing foot and reported to the closest 1cm.

Countermovement Vertical Jump (CMJ)

CMJ data were collected using the Just Jump mat (Probiotics, Huntsville, AL). Attempts were conducted adopting the arms akimbo position and utilising a self-selected countermovement depth. Attempts were disqualified if participants abandoned the arms akimbo position or actively flexed at the knee or hip during flight. CMJ was measured to the nearest 0.1cm reported via the Just Jump handheld unit.

505 Change of Direction Test (505COD)

Change of direction ability through the horizontal plane was assessed via the 505COD test. The methodology for the 505COD was conducted as per established methods (Draper & Lancaster, 1985). This involved a 15m linear sprint from a static start, a 180° turn on the nominated leg ensuring contact with a turn line, and a 5m recovery sprint through an identified finish line. The time expired during the final 5m of the 15m linear sprint, turn, and 5m return sprint was recorded. Participants completed two attempts for each turning leg (R/L) with the mean score of the best attempt from each leg being used for analysis.

T-Drill Test (T-Test)

Multi-directional speed and change of direction ability was assessed via the T-Test. The methodology for the T-Test was used as per established methods (Semenick, 1990). This involved completing a pre-planned course touching a series of cones laid out in a T shape, requiring a combination of maximal sprinting, side shuffling, and backpedalling.

10/20m Sprint

Linear speed and acceleration was assessed over distances of 10/20m as per previously reported match-based observations of youth soccer players (Buchheit et al., 2010).

Statistical Analysis:

Prior to analysis, the assumption of normality was verified using the Shapiro-Wilk test. A two-way random effects intra-class correlation coefficient (ICC) with absolute agreement and coefficient of variation (CV) was used to evaluate relative test-retest reliability. Standardised effect size (d), reported as Cohen's d using the pooled SD as the denominator, was calculated to evaluate the magnitude of the test-retest differences. As per guidelines provided by Atkinson & Nevill (1998) and Hopkins (2000), the tests were deemed as reliable if they met the following criteria: good-excellent ICC (>0.80), moderate CV ($\leq 10\%$), and a trivial or small effect size ($d < 0.60$). For the separate analyses associated with playing standards and age groups, test scores were standardised using within-group z-scores. This involved allocating standardised scores within-age or within-playing standard groups, and then collapsing across levels prior to analysis. This allowed for comparisons between playing standards (using standardised within-age group z-scores) removing potential age effects, and between age groups (using standardised within-playing standard z-scores) removing potential playing standard effects. The mean score of trial 1 and trial 2 was used for comparisons between levels and age. Identified/unidentified players were compared using an independent samples t-test using z-scores, playing standards and age groups were compared via a one-way analysis of variance (ANOVA) using z-scores, with a Bonferroni post-hoc test being implemented to identify differences between groups. Discriminant function analysis was conducted to derive

a predictive model for classifying youth players as unidentified or identified based upon fitness test performance. Percentages of correct classification and canonical correlation coefficients were noted. Statistical significance was set at $p \leq 0.05$.

3.3 Results

Reliability of physical performance characteristics

Table 3.1 shows reliability data for all fitness test components at each age group. The majority of field-based fitness tests selected within this study proved to be reliable measures of physical performance across all age groups (ICC = 0.83-0.97; $p < 0.01$). However, the 505COD and T-Test tests showed weaker reliability in younger participants (U11/U12) (ICC = 0.57-0.79; $p < 0.01$). In addition, the 10m and 20m sprint showed weaker reliability (ICC < 0.80) in the U12 (ICC = 0.73) and U17 age groups (ICC = 0.78). **Figure 3.2** shows mean performance differences between trials for the 505COD and T-Test across age groups.

Validity of physical performance characteristics

Identified players were taller (0.11 ± 0.98 vs. -0.18 ± 0.99 ; $p < 0.01$) and heavier (0.10 ± 1.00 vs. -0.17 ± 0.99 ; $p < 0.01$) compared to unidentified players. Playing standard comparisons revealed that performance players were taller (0.30 ± 0.12 vs. -0.24 ± 0.13 ; $p = 0.044$) and heavier (0.31 ± 0.12 vs. -0.26 ± 0.13 ; $p = 0.036$) than amateur players, however no differences were observed for stature or body mass between amateur-development or development-performance player groups. No differences were observed between identified and unidentified groups or playing standards for birth month, or birth quarter across all age groups, or between playing position.

Figure 3.3 shows validity data between unidentified and identified player groups. Grip strength (0.16 ± 1.00); SBJ (0.30 ± 0.93); CMJ (0.16 ± 1.01); 505COD (0.23 ± 1.01); and T-Test (0.16 ± 0.98) performance was higher in the identified player group ($p < 0.01$), and also on the 20m sprint test (0.10 ± 0.99 ; $p = 0.012$). The 10m sprint was the only test

Table 3.1 Between-day test-retest reliability of field-based fitness tests across age groups U11-U17.

		U11 (n=26)	U12 (n=51)	U13 (n=75)	U14 (n=59)	U15 (n=81)	U16 (n=46)	U17 (n=35)
Grip Strength	Trial 1 (x ± SD) [kg]	17.8 ± 2.6	18.1 ± 3.6	21.5 ± 4.5	25.3 ± 5.3	33.2 ± 7.5	37.7 ± 7.2	37.5 ± 7.3
	Trial 2 (x ± SD) [kg]	17.7 ± 2.9	18.7 ± 3.3	22.1 ± 4.8	25.9 ± 5.8	33.4 ± 7.2	38.3 ± 6.3	37.8 ± 7.0
	ICC (CI)	0.93 (0.85-0.97)	0.83 (0.71-0.91)	0.85 (0.76-0.90)	0.89 (0.81-0.93)	0.92 (0.87-0.95)	0.92 (0.84-0.96)	0.88 (0.77-0.94)
	CV (%)	4.4	8.2	8.3	6.7	6.4	5.6	5.8
	<i>d</i>	0.04	0.17	0.13	0.11	0.03	0.09	0.03
SBJ	Trial 1 (x ± SD) [cm]	154.7 ± 12.6	159.3 ± 13.8	171.4 ± 17.8	181.2 ± 17.8	195.6 ± 16.3	201.4 ± 21.6	214.0 ± 21.6
	Trial 2 (x ± SD) [cm]	153.9 ± 13.8	158.4 ± 15.9	174.3 ± 22	183.8 ± 17.8	195.8 ± 17.8	203.6 ± 22.1	214.2 ± 22.1
	ICC (CI)	0.93 (0.84-0.97)	0.90 (0.83-0.95)	0.90 (0.84-0.94)	0.96 (0.92-0.97)	0.95 (0.93-0.97)	0.93 (0.86-0.96)	0.97 (0.93-0.98)
	CV (%)	2.5	2.3	3.0	2.5	2.1	2.2	1.89
	<i>d</i>	0.06	0.06	0.14	0.15	0.01	0.1	0.003
CMJ	Trial 1 (x ± SD) [cm]	36.0 ± 4.3	36.7 ± 4.6	36.8 ± 4.9	40.4 ± 6.6	43.8 ± 4.7	47.6 ± 5.3	48.3 ± 6.5
	Trial 2 (x ± SD) [cm]	35.4 ± 5.1	36.5 ± 4.8	36.8 ± 5.3	41.0 ± 6.4	43.9 ± 4.6	47.5 ± 6.4	48.1 ± 6.1
	ICC (CI)	0.90 (0.78-0.96)	0.94 (0.90-0.97)	0.87 (0.80-0.92)	0.94 (0.91-0.97)	0.90 (0.85-0.94)	0.95 (0.90-0.97)	0.96 (0.92-0.98)
	CV (%)	4.0	3.2	5.0	3.8	3.6	3.2	2.8
	<i>d</i>	0.13	0.04	0.001	0.09	0.02	0.02	0.05
COD505	Trial 1 (x ± SD) [s]	2.84 ± 0.13	2.76 ± 0.14	2.66 ± 0.16	2.58 ± 0.12	2.48 ± 0.10	2.45 ± 0.13	2.43 ± 0.13
	Trial 2 (x ± SD) [s]	2.96 ± 0.14	2.89 ± 0.20	2.68 ± 0.18	2.60 ± 0.14	2.50 ± 0.12	2.47 ± 0.12	2.42 ± 0.13
	ICC (CI)	0.61 (0.12-0.85)	0.57 (0.08-0.78)	0.91 (0.86-0.94)	0.89 (0.82-0.94)	0.85 (0.77-0.91)	0.86 (0.74-0.93)	0.97 (0.93-0.98)
	CV (%)	3.3	3.6	1.9	1.7	1.9	2.2	1.0
	<i>d</i>	0.89	0.75	0.12	0.15	0.18	0.16	0.1
T-Test	Trial 1 (x ± SD) [s]	11.83 ± 0.79	11.62 ± 0.52	11.27 ± 0.74	10.88 ± 0.60	10.24 ± 0.46	9.96 ± 0.50	9.86 ± 0.59
	Trial 2 (x ± SD) [s]	12.17 ± 0.70	11.86 ± 0.79	11.45 ± 0.85	10.97 ± 0.67	10.35 ± 0.46	9.98 ± 0.53	10.03 ± 0.74
	ICC (CI)	0.79 (0.46-0.91)	0.75 (0.54-0.86)	0.89 (0.80-0.93)	0.94 (0.89-0.96)	0.87 (0.78-0.92)	0.95 (0.90-0.97)	0.91 (0.76-0.96)
	CV (%)	3.1	3.0	2.3	1.5	1.6	1.3	1.9
	<i>d</i>	0.46	0.36	0.26	0.14	0.24	0.04	0.25
Sprint 10m	Trial 1 (x ± SD) [s]	2.05 ± 0.08	1.99 ± 0.07	1.95 ± 0.11	1.90 ± 0.11	1.82 ± 0.10	1.75 ± 0.09	1.73 ± 0.09
	Trial 2 (x ± SD) [s]	2.05 ± 0.09	2.01 ± 0.09	1.96 ± 0.11	1.93 ± 0.10	1.83 ± 0.10	1.77 ± 0.09	1.76 ± 0.09
	ICC (CI)	0.85 (0.66-0.94)	0.73 (0.42-0.88)	0.90 (0.83-0.94)	0.84 (0.71-0.90)	0.93 (0.88-0.95)	0.94 (0.88-0.97)	0.78 (0.57-0.89)
	CV (%)	1.7	2.2	2.0	2.2	1.7	1.5	2.4
	<i>d</i>	0.0001	0.25	0.09	0.29	0.1	0.22	0.3
Sprint 20m	Trial 1 (x ± SD) [s]	3.67 ± 0.14	3.59 ± 0.16	3.50 ± 0.21	3.39 ± 0.20	3.23 ± 0.18	3.09 ± 0.15	3.08 ± 0.15
	Trial 2 (x ± SD) [s]	3.69 ± 0.20	3.64 ± 0.19	3.54 ± 0.21	3.42 ± 0.19	3.26 ± 0.19	3.16 ± 0.17	3.11 ± 0.15
	ICC (CI)	0.85 (0.58-0.92)	0.73 (0.67-0.91)	0.90 (0.89-0.97)	0.83 (0.86-0.96)	0.93 (0.90-0.97)	0.94 (0.63-0.96)	0.78 (0.85-0.97)
	CV (%)	1.8	2.3	1.6	1.8	1.5	2.0	1.4
	<i>d</i>	0.12	0.28	0.19	0.15	0.16	0.44	0.2

n = sample size; x ± SD = mean ± standard deviation; ICC = intra-class correlation, all p<0.01; CI = confidence interval; CV = coefficient of variation; *d* = Cohen's *d* effect size

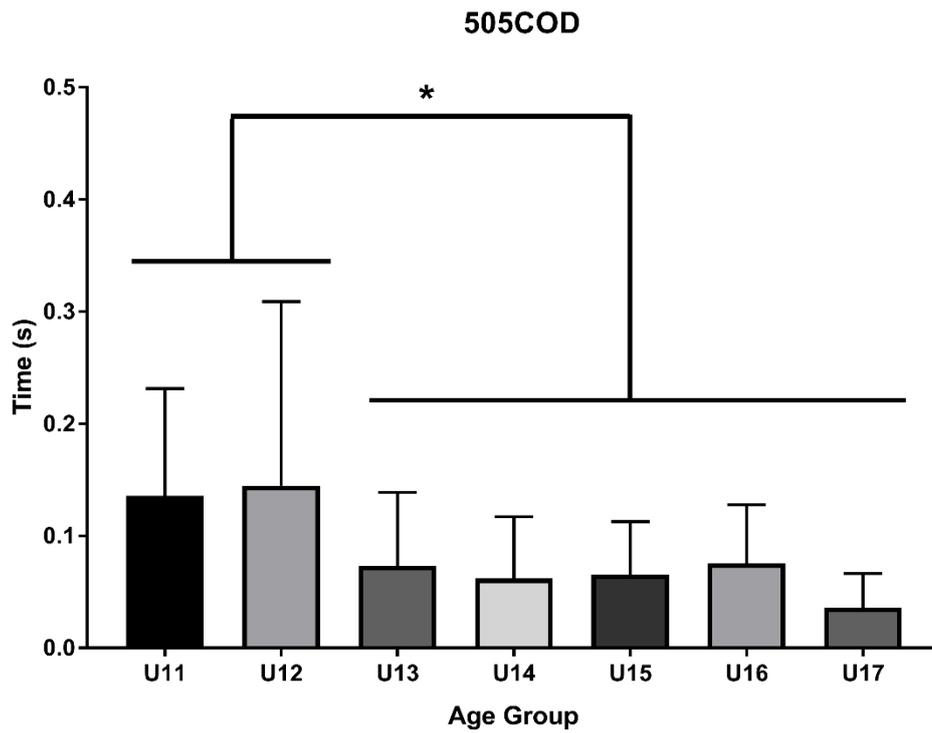
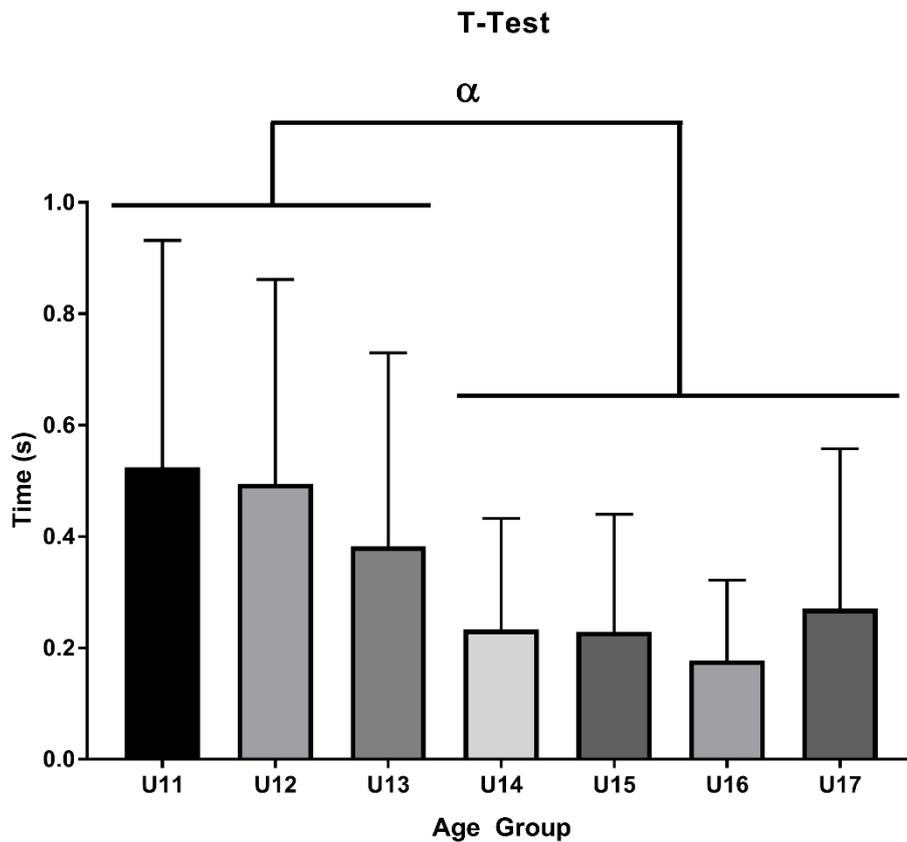
A**B**

Figure 3.2 Between-trial mean difference comparisons for COD tests across individual age groups. **A:** 505COD, **B:** T-Test. * indicates differences between U11/U12 and U13-U17 age groups; α indicates differences between U11-U13 and U14-U17 age groups ($p < 0.01$).

demonstrating non-significant differences between the unidentified (-0.01 ± 0.95) and identified (0.01 ± 1.02) player groups ($p=0.829$).

Figure 3.4 shows validity data between amateur, development, and performance playing standards. The CMJ was the only test that demonstrated increases at each of the 3 playing standards in the hypothesised direction (development > amateur, $p=0.022$; performance > development; $p<0.01$). Amateur players had lower grip strength (-0.26 ± 0.93); SBJ (-0.49 ± 0.88); 505COD (-0.37 ± 0.89); and T-Test (-0.26 ± 0.96) compared to both development and performance players ($p<0.01$). The 20m sprint was slower for amateur (-0.17 ± 0.98) compared to development (0.20 ± 1.12 ; $p<0.01$), however not when compared to performance players (0.02 ± 0.85 ; $p=0.127$). No differences were observed between club levels for the 10m sprint test. SBJ (0.57 ± 0.92) and 505COD (0.61 ± 0.82) tests were higher for development compared to performance players ($p<0.01$).

No differences were observed between U11/U12 age groups for any measure; U12/U13 age groups for CMJ ($p=0.954$) and T-Test ($p=0.108$), a tendency for U13 players to be faster over the 10m sprint ($p=0.056$) and 20m sprint ($p=0.065$); and U16/U17 where no differences were observed for any measure except SBJ ($p=0.019$). Performance differences were observed between all remaining age groups and tests in the hypothesised direction (U17 > U11; $p<0.01$), except for U12/U13 age groups for grip strength ($p=0.025$) and SBJ ($p=0.012$). Whilst still significant, these were not observed at the ($p<0.01$) level as reported for the majority of measures.

Discriminant function analyses indicated that the field-based fitness tests discriminated between the unidentified and identified players; $\chi^2 (7) = 101.646$, $p<0.01$, with 70.2% of

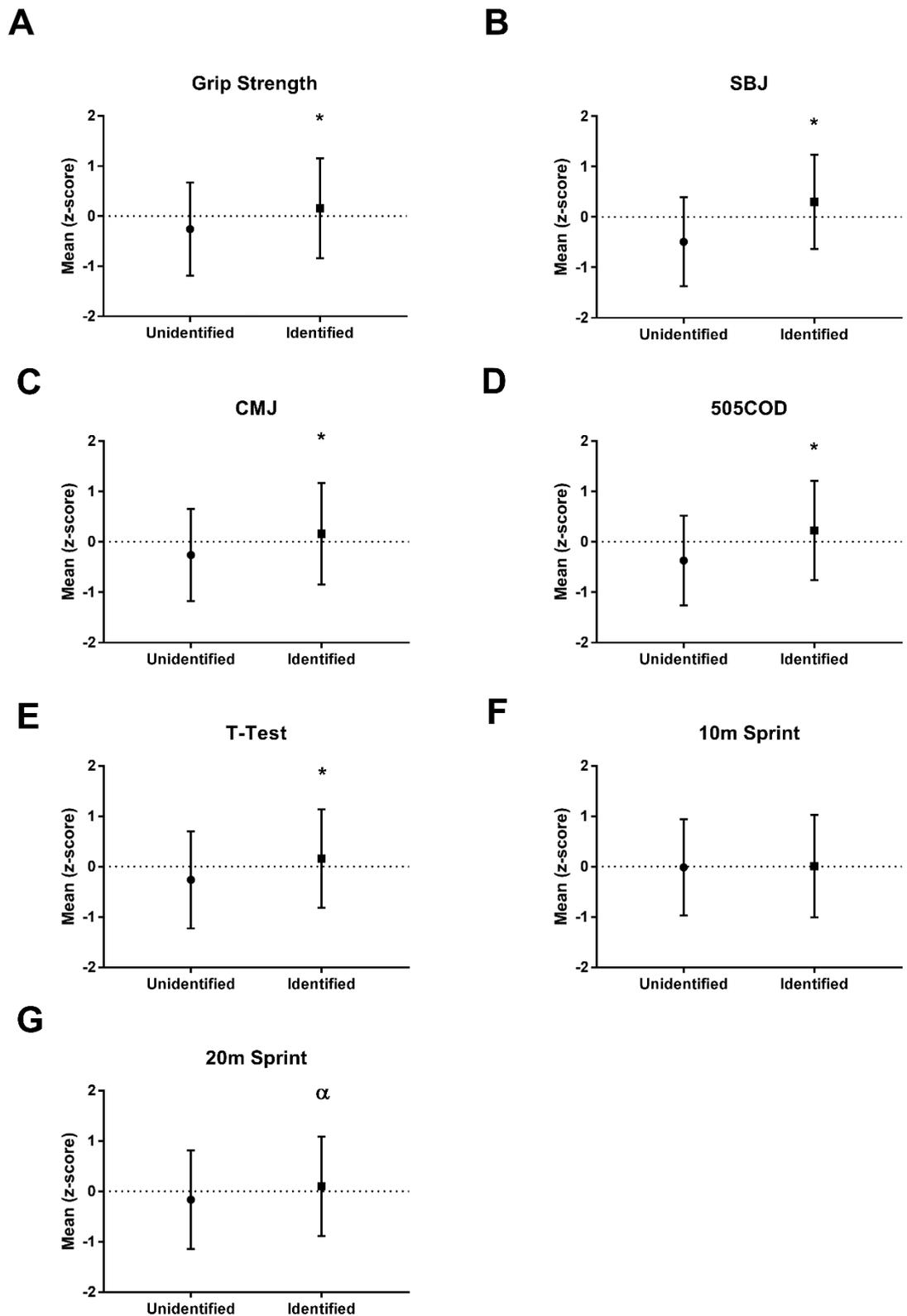


Figure 3.3 Z-score mean differences on performance tests between unidentified and identified player groups. **A:** Grip Strength, **B:** SBJ, **C:** CMJ, **D:** 505COD, **E:** T-Test, **F:** 10m Sprint, **G:** 20m Sprint. * indicates higher than unidentified ($p < 0.01$); α indicates higher than unidentified ($p < 0.05$).

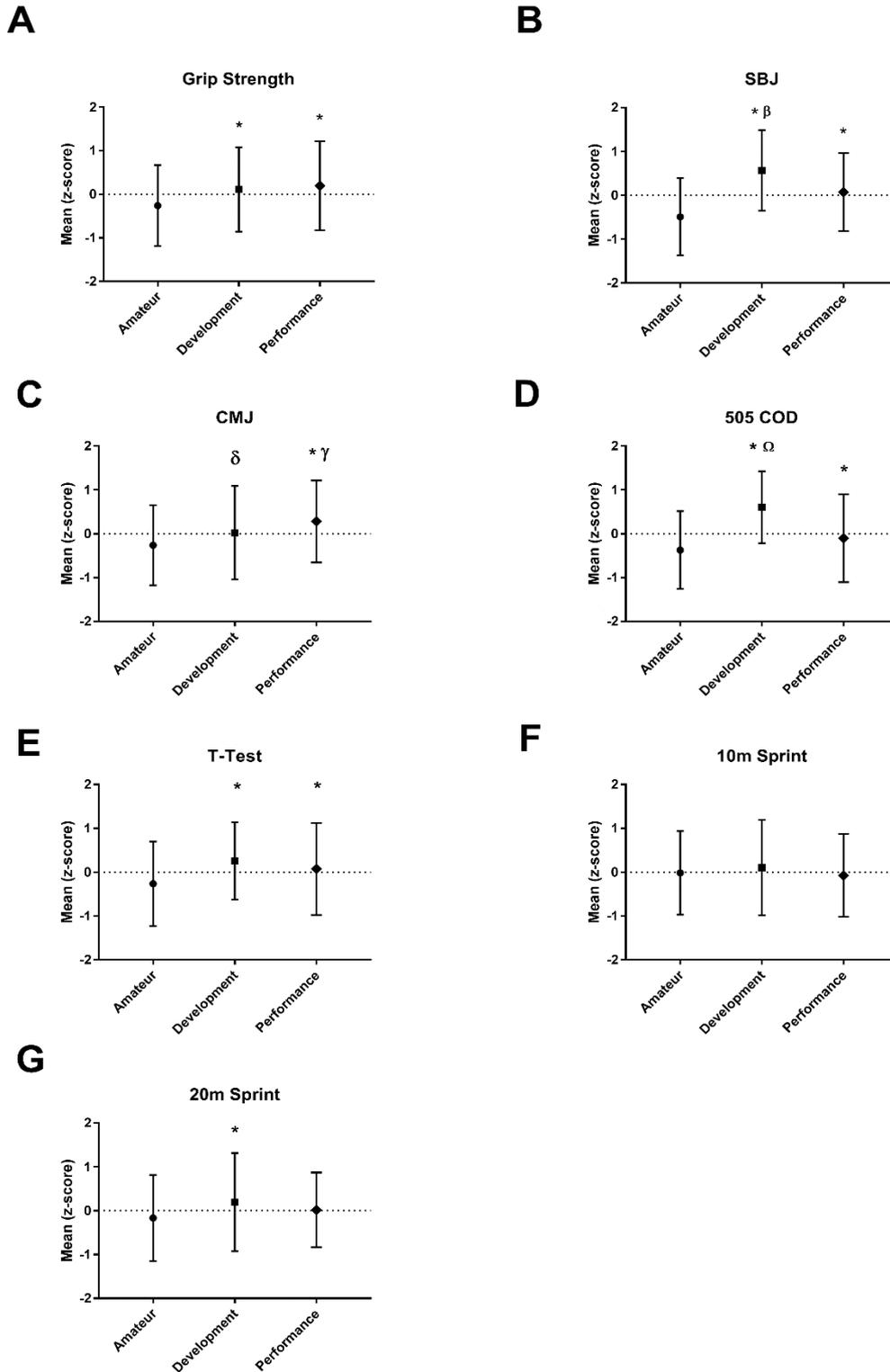


Figure 3.4 Z-score mean differences on performance tests between different playing standards. **A:** Grip Strength, **B:** SBJ, **C:** CMJ, **D:** 505COD, **E:** T-Test, **F:** 10m Sprint, **G:** 20m Sprint. * indicates higher than amateur; α indicates higher than development; β indicates higher than performance ($p < 0.01$). δ indicates higher than amateur; γ indicates higher than development; Ω indicates higher than performance ($p < 0.05$).

players being correctly classified. Inspection of the canonical correlation coefficients revealed that this discrimination was largely due to performance on the SBJ ($r = 0.75$) and 505COD ($r = 0.54$) tests. The additional tests within the testing battery did not make an important contribution to the discriminant function ($r < 0.40$), with 10m sprint performance contributing to group membership least ($r = 0.02$).

3.4 Discussion

This study aimed to evaluate the reliability of commonly-used field based fitness tests, and to evaluate the construct validity of a field-based fitness testing battery to discriminate across the entire spectrum of ages and performance levels of male youth soccer players, within a national governing body structure for soccer. The field-based fitness tests used within this study were mostly reliable (acceptable between-day reliability) and valid (able to discriminate between unidentified and identified player groups) in male youth soccer players. However, the lower reliability of the COD tests within younger participants, and the inability of field-based fitness tests to discriminate between development-performance playing standards prevent congruous implementation of this testing battery across the entire sample of the present study.

In agreement with previous findings across comparable age ranges (Hulse *et al.*, 2013), test-retest reliability was reported as “good-excellent” for the majority of age groups across tests, an exception being “acceptable” ICC values reported for the 10/20m sprint tests for U12/U17 age groups (**Table 3.1**). Nevertheless, despite the lower ICC values for U12/U17 age groups, the CV and ES for these groups suggests acceptable between-day test reliability. The lower reliability values observed for the 505COD and T-Test change of direction tests for younger players however, is a novel finding of this study. Whilst the CV values reported for the 505COD are still within range of what is typically considered as “good reliability” (CV<10%) (Atkinson & Nevill, 1998), the moderate effect size ($d = 0.75-0.89$) and lower ICC (0.57-0.61) within younger age ranges (U11-U12) show higher variability in this test compared to other measures (**Figure 3.2**). Due to the physical complexity and demand on eccentric/concentric strength and power of these tests (Lloyd *et al.*, 2013), it is likely that limited physical

development and early stage of maturation associated with the younger players within this study could result in increased variability in test performance (Gil, Ruiz *et al.*, 2007; Paul & Nassis, 2015; Pearson *et al.*, 2006). Lower levels of test-retest reliability, moderate effect sizes and differences in performance for the 505COD and T-Test in the young age groups (U11-U12) suggest that these tests may be less suitable as a measure to evaluate change of direction (COD) performance in young soccer players.

In agreement with previous findings, identified players were larger in stature and body mass comparative to unidentified players (Figueiredo *et al.*, 2009). Additionally, six of the seven fitness tests within the testing battery displayed differences between unidentified and identified player groups in the hypothesised direction (identified players scoring better than unidentified) (**Figure 3.3**). It is possible that these anthropometric and physical discrepancies are due to differences in maturity status between the unidentified and identified player groups. A wealth of previous evidence suggests youth players playing at higher competitive standards often have an advanced maturity status than their chronologically age-matched peers (Cumming *et al.*, 2018; Gouvêa *et al.*, 2017; Lovell *et al.*, 2015). This has been reported as an influencer within the selection/deselection process within youth soccer (Figueiredo *et al.*, 2009; Malina *et al.*, 2010), however there is limited evidence to suggest these maturity and anthropometric differences observed during adolescence contribute to future professional status (le Gall *et al.*, 2010; Ostojic *et al.*, 2014). In addition, performance improvements relative to chronological age groups increased between ages 13-15 years, with inconsistencies in performance improvements observed at the lower (U11-U13) and upper (U16/U17) ranges of this sample. This finding is supported by previous research, reporting peak physical development transpiring at peak height velocity, typically reported between 13-

15 years in active adolescent boys (Cumming *et al.*, 2018; Gouvêa *et al.*, 2017; Lovell *et al.*, 2015; Philippaerts *et al.*, 2006).

Despite the proclaimed importance of acceleration and short sprint ability associated with competitive youth soccer (Gil, Ruiz *et al.*, 2007; le Gall *et al.*, 2010; Rebelo *et al.*, 2013), the 10m sprint was the only test demonstrating no differences between groups (**Figure 3.4**). This finding could be due to the convention of younger athletic populations participating in multiple sports simultaneously, and the translation of acceleration and short duration sprint ability across various athletic activities. However, observed differences between playing standards demonstrated that only the CMJ test displayed differences at each playing standard in the anticipated direction (performance>development>amateur). Surprisingly, development players scored better than both amateur and performance player groups on the 505COD and SBJ tests. These findings suggest there may be a physical barrier between unidentified and identified player categories, however, a physical evaluation alone is insufficient to discriminate between the development and performance players within this study. Additional factors associated with soccer performance must therefore be considered when looking to discriminate between players of different standards within an identified player population.

Interpretation of findings from the discriminant function analysis supports the notion that the field-based testing battery, used in this study, possessed construct validity, demonstrating a 70.2% success rate of correctly classifying unidentified and identified players. Classifications were mostly influenced based on performance on the SBJ and 505COD tests. These findings align with previous suggestions promoting the suitability of a field-based fitness testing battery as a valid and sensitive tool to discriminate between identification status (Unnithan

et al., 2012; Vaeyens *et al.*, 2006). Our findings also highlight the importance of muscular power and COD ability within youth soccer.

A limitation of this study was the absence of a field-based measure of cardio-vascular endurance, for example the YYIRT L1. Whilst the YYIRT L1 was within the initial testing battery protocol, it was removed following an unwillingness of development/performance coaches to allow their players to complete this test due to the perceived fatigue associated with completing it. Levels of cardio-vascular fitness are often reported as a key determinant of elite and identified youth soccer players (Buchheit *et al.*, 2010; Gil, *et al.*, 2007; le Gall *et al.*, 2010; Mujika, Santisteban *et al.*, 2009; Stølen *et al.*, 2005), therefore may have added to the discriminative ability of this field-based fitness testing battery. Finally, a lack of measure of maturity status is a further limitation of this study. The effects of advanced maturity status on physical performance tests are well established within current literature (Figueiredo *et al.*, 2009; le Gall *et al.*, 2010). Whilst it is acknowledged that maturity status may be a contributing factor regarding the differences in physical performance demonstrated by this study, our study design is ecologically valid according to the national governing body for soccer appropriate to our sample. Therefore, resultant of the current tendency to categorise players by chronological age, rather than maturity status, these findings suggest that physical ability continues to influence playing standard selection within youth soccer players in Scotland.

3.5 Conclusion

Coaches and practitioners should be aware of the potential lower reliability of COD tests in young soccer players. This may result in potential issues when interpreting performance test results with younger age groups (U11/U12) as the magnitude of change in COD performance may be lower than variability within the test. The results of the present study suggest that whilst a comprehensive field-based fitness testing battery can discriminate between two distinct sample groups (unidentified vs. identified), a physical fitness testing battery alone is insufficient to discriminate between players of varied ability within an identified group of youth soccer players.

VIII – SYNTHESIS (CHAPTER 3 – CHAPTER 4)

Following the lower reliability for COD tests in younger youth soccer athletes, observed in **Chapter 3** of this thesis, this next experimental chapter (**Chapter 4**) aims to explore reliability of alternative COD tests, with the aim of identifying suitable measures to assess this physical quality across entire age ranges recruited by youth soccer academies. As discussed in **Section 2.3.1.3**, COD tests vary in duration and physical demand. Resultant of the lower reliability for COD tests observed during **Chapter 3**, COD tests shorter in duration and physical demand will be employed in the subsequent chapter. It is hypothesised that due to the reduction in test complexity and physical demands, of these selected tests, reliability may be improved in this physically naive sample. Additionally, given that almost all physical actions in soccer occur in response to a stimulus (**Section 2.2.1.1**), and assessment of this physical quality (agility) is more ecologically valid, reliability of this quality will also be assessed in this chapter.

Finally, when improving agility performance as part of TD, knowledge of contributing factors to this skill, remain unknown within this sample. Given the vast physical and biological changes that occur throughout the adolescent period, it is hypothesised that relationships may vary across age groups, therefore requiring a varied approach to training and development during these ages.

A better understanding of the reliability of these measures alongside relationships between associated factors and agility performance will provide valuable information contributing towards a more representative TI and TD process.

CHAPTER 4

CHANGE OF DIRECTION AND AGILITY PERFORMANCE ASSESSMENT IN PROFESSIONAL YOUTH SOCCER PLAYERS

Abstract

Ability to perform changes of direction (COD), both as a closed skill, and in response to a stimulus is crucial within soccer. It is widely accepted that agility performance is comprised of a combination of perceptual/decision making and neuromuscular factors. However, relationships between these contributing factors and agility performance remain ambiguous within the literature. The purpose of this study was to examine between-day reliability of COD and agility tests and to examine relationships between a range of physical and perceptual/decision making tests and agility performance across a broad spectrum of ages of youth soccer players. Eighty-six elite youth soccer players (U11-U17) signed to a professional soccer academy playing at the top competitive level of the Scottish Football Association youth soccer structure participated in a comprehensive fitness testing battery examining physical and perceptual-cognitive abilities relevant to the skill of agility. Participants repeated the COD and agility tests under matched conditions after a 7-day washout period. The COD and agility tests possessed good-excellent between-day reliability for our sample (ICC = 0.82-0.91; CV = 1.5-2.0; d : 0.00-0.08). However, small-moderate negative relationships between age and mean between trial differences were reported for COD ($r = -0.28$) and between both age ($r = -0.41$) and age at peak height velocity ($r = -0.39$) for agility tests. Linear sprint and pre-planned COD ability displayed large-very large relationships to agility performance ($r = 0.63-0.71$), whereas performance on a lower body reaction time test displayed moderate relationships to agility performance ($r = 0.31$). Our findings suggest that COD and agility tests adopted within this study possess good between-day reliability, however, may be more variable in younger and less mature individuals. Moreover, short-distance linear sprint and pre-planned COD ability largely related with agility performance within this sample.

4.1 Introduction

The open and intermittent nature of competitive team sport places high demands on players to interpret and react to multiple stimuli on a constant basis (Young, Dawson, & Henry, 2015). Between 1000 and 1500 discrete movement changes have been observed within a competitive soccer match, with changes in activity occurring, approximately, every 3.5s (Strudwick *et al.*, 2002). As discussed within **Section 2.2** of this thesis, substantial increases in physical demands, notably sprint frequency and explosive accelerations, have been observed in elite soccer players within competition (Barnes *et al.*, 2014). Subsequently, ability to efficiently perform precise and accurate COD both as a closed skill, and in response to stimuli, is both crucial, and increasing in importance, within the sport of soccer. On occasions, COD and agility have been wrongly used interchangeably, creating confusion (Young, Dawson, & Henry, 2015). However, it has recently been accepted and clarified that prevalence of external stimuli, and demands to interpret and react to this stimuli, distinguishes the skill of agility from the pre-planned and closed skill of COD ability (Young, Dawson, & Henry, 2015). Findings from **Chapter 3** suggesting that COD performance assessment may be unreliable in young, immature players, combined with its importance within the discrimination between unidentified and identified players warrants further investigation into the assessment of this physical characteristic. Similarly, the contribution of COD to agility performance calls for further study into the reliability of this characteristic within a youth soccer cohort.

It is widely accepted that agility performance is comprised of a combination of both perceptual/decision making and physical COD factors (Sheppard & Young, 2006; Young, James, & Montgomery, 2002). However, relationships between these contributing factors and agility performance remain ambiguous within the literature. Physical actions constitute the greatest proportion of time to complete an agility test (Mendez-Villanueva *et al.*, 2011), yet

relationships comparing COD ability and agility test performance have ranged from high ($r = 0.70$) (Farrow et al., 2005), to low ($r = 0.32$) (Sheppard *et al.*, 2006) within team sport athletes. Moreover, low to moderate relationships are reported relating agility performance to: 1) strength/power characteristics ($r = -0.28$ to $r = -0.36$) (Henry, Dawson, Lay, & Young, 2013; Spiteri *et al.*, 2014); 2) linear sprint ability ($r = 0.33$ to $r = 0.41$) (Gabbett, Kelly, & Sheppard, 2008; Sheppard *et al.*, 2006); and 3) anthropometric measurements ($r = 0.10$ to $r = 0.32$) (Naylor & Greig, 2015). In addition to physical factors, reaction time is also a critical component of many team sports, due to the requirement to respond to multiple stimuli within a constantly-changing environment (Spiteri *et al.*, 2013). Several previous studies have included generic perceptual-cognitive assessments when evaluating contributors to agility performance (Naylor & Greig, 2015; Scanlan *et al.*, 2014). However, it is suggested that, to elicit a reaction response appropriate to the desired task, the compatibility and specificity of the stimulus must be considered (Spiteri *et al.*, 2013).

Whilst essential for successful senior team sport performance, agility is also considered an important physical quality for development throughout childhood and adolescence (Lloyd & Oliver, 2012). However, studies exploring this skill, within a youth athletic sample, are scarce (Lloyd *et al.*, 2013; Pojskic *et al.*, 2018). It is suggested that cognitive decision-making ability is influenced by experience (Paul et al., 2016), and therefore performance differences may be less apparent in athletes with limited previous exposure to appropriate situations, such as youth athletes. The pre-pubertal and adolescent years have been shown to represent an opportunity for children to enhance strength (Behringer *et al.*, 2011) and speed (Mendez-Villanueva *et al.*, 2011) qualities, both of which are components of agility (Sheppard & Young, 2006; Young *et al.*, 2002). Moreover, given the vast physical and neural developments experienced throughout maturation (Malina *et al.*, 2015), relationships between agility and

its various associated perceptual/decision making and physical factors may vary throughout adolescence (Lloyd *et al.*, 2013; Lloyd & Oliver, 2012). Both previous research (Taylor *et al.*, 2018), and findings from **Chapter 3** of this thesis has shown that reliability of COD test performance may vary across adolescence. To our knowledge, no study exists examining relationships between a comprehensive battery of tests and an agility test across a broad spectrum of adolescent team sport athletes. Therefore, if COD and agility performance cannot be reliably assessed in child-youth soccer athletes, an improved understanding of the most closely related contributors would be valuable information for coaches and practitioners seeking to improve COD and agility parameters within this sample.

Accordingly, the purpose of this study was to: i) examine the reliability of alternative COD tests, and an agility test across a broad spectrum of ages of youth soccer players, ii) examine the relationships between a range of physical and perceptual/decision making tests and agility performance across a broad spectrum of ages of youth soccer players, and iii) to identify any potential changes in the strength of relationships observed between different ages of youth soccer players. It is hypothesised that the COD and agility tests will demonstrate good reliability, however, reliability may be lower within the younger age groups as previously observed within **Chapter 3** of this thesis. It is also hypothesised that measures of linear sprint, pre-planned COD ability, and reaction time will display moderate-large relationships with agility performance, due to common variance, and that these relationships will increase in strength for the older age groups within our sample.

4.2 Methods

Participants:

Eighty-six Scottish youth soccer players (mean \pm SD [range]: age 13.6 ± 2.0 [10.6-17.3] years; stature 160.8 ± 13.7 [134.2-193.9] cm; mass 50.1 ± 13.0 [27.5-78.7] kg) volunteered to participate in this study. Participants were signed to an elite professional soccer academy playing at the top competitive level of the Scottish Football Association (SFA) youth soccer structure. Participants were categorised within the following age groups as specified by the SFA: U11/U12 (n = 31), U13/U14 (n = 23), and U15-U17 (n = 32). Prior to conducting any trials, participant and parental/guardian consent was gained alongside providing comprehensive written and oral explanations about the study. The study received institutional ethical approval.

Design:

Participants completed 2 testing sessions, 7 days apart. During the first session, anthropometric data including body mass, standing stature, and sitting height were collected, alongside performance data from the squat jump (SJ), countermovement jump (CMJ), 10m/40m sprint, a modified 505 COD test (m505COD), grip dynamometry (grip strength), Y-sprint drill in both pre-planned (Y-SprintPRE) and reactive (Y-SprintREACT) conditions, and a lower body reaction time test (LBRTT). During the second session, participants completed only the m505COD, Y-SprintPRE, and Y-SprintREACT tests to assess between-day reliability for these measures. To account for circadian variability (Drust et al., 2005), both testing sessions were completed at the same time of day. Testing sessions were completed a minimum of 48hours following a competitive game, and in absence of strenuous exercise within 24hours prior. Testing sessions were conducted indoors ($\sim 22^{\circ}\text{C}$) on a synthetic 4G pitch. Prior to

conducting any tests, participants conducted a standardised warm-up consisting of light aerobic activity, dynamic stretching, progressive sprinting, and sub-maximal pre-planned changes of direction.

Procedures:

Following the standardised warm-up, participants received verbal instruction and demonstrations from the research team immediately prior to conducting 2-3 familiarisation attempts for each test. For tests where electronic timing gates were used, gates were adjusted to an appropriate height as per the mean stature of the sample group, and start positions were standardised as self-selected starts from 0.7m behind the start gate (Haugen & Buchheit, 2016). Data were collected using the Witty Dual Beam Timing System (Microgate, Bolzano, Italy) with total time being reported to the nearest 0.01 s. Unless otherwise stated, participants completed 3 attempts of each test with the best attempt being selected for analysis (Al Haddad *et al.*, 2015). Recovery intervals between attempts were standardised at 3minutes for each test.

Anthropometrics/Maturity Status

Standing stature and sitting height was assessed using a free-standing stadiometer (Seca, Birmingham, UK) and reported to the nearest 0.1 cm. Body mass was assessed using digital floor scales (Seca, Birmingham, UK) and reported to the nearest 0.1 kg. Somatic maturity estimates were made for all participants via non-invasive methods. A regression equation was used to estimate years from age at peak height velocity (maturity offset) (Mirwald *et al.*, 2002), with predicted age at peak height velocity (APHV) in years estimated as chronological age minus maturity offset (Malina *et al.*, 2015). Calculations required standing stature, sitting

height, and mass values described above, alongside chronological age at the time of measurement.

Squat Jump/Countermovement Jump

SJ and CMJ data were collected using the Just Jump mat (Probiotics, Huntsville, AL). Attempts were conducted adopting the arms akimbo position and utilising a self-selected countermovement depth. Attempts were disqualified if participants abandoned the arms akimbo position or actively flexed at the knee or hip during flight. For the SJ, participants were required to pause momentarily (~1 s) at their self-selected countermovement depth before receiving an audible 'jump' signal from the research team initiating their jump. For the CMJ, participants completed a ballistic descent-ascent to their self-selected depth. Data were reported to the nearest 0.1 cm.

10/40m Sprint

Acceleration and maximal running speed were assessed over a distance of 10/40 m, respectively, as per previously reported match-based observations of youth soccer players (Buchheit *et al.*, 2010; Mendez-Villanueva *et al.*, 2011).

Grip Dynamometry

Grip strength was examined using a Takei 5001 analogue dynamometer (Takei Scientific Instruments Co., Niigata-City, Japan). Attempts were collected from participants' dominant hand, and with the appropriate hand spacing adjusted for each individual as per manufacturer guidelines. Participants were instructed to hold the dynamometer above head with a locked arm and apply maximum pressure by squeezing the handle of the dynamometer. Over a 5-

second period, the dynamometer was lowered in an arc towards the participant's hip maintaining a locked arm. Data were reported to the nearest 0.5 kg.

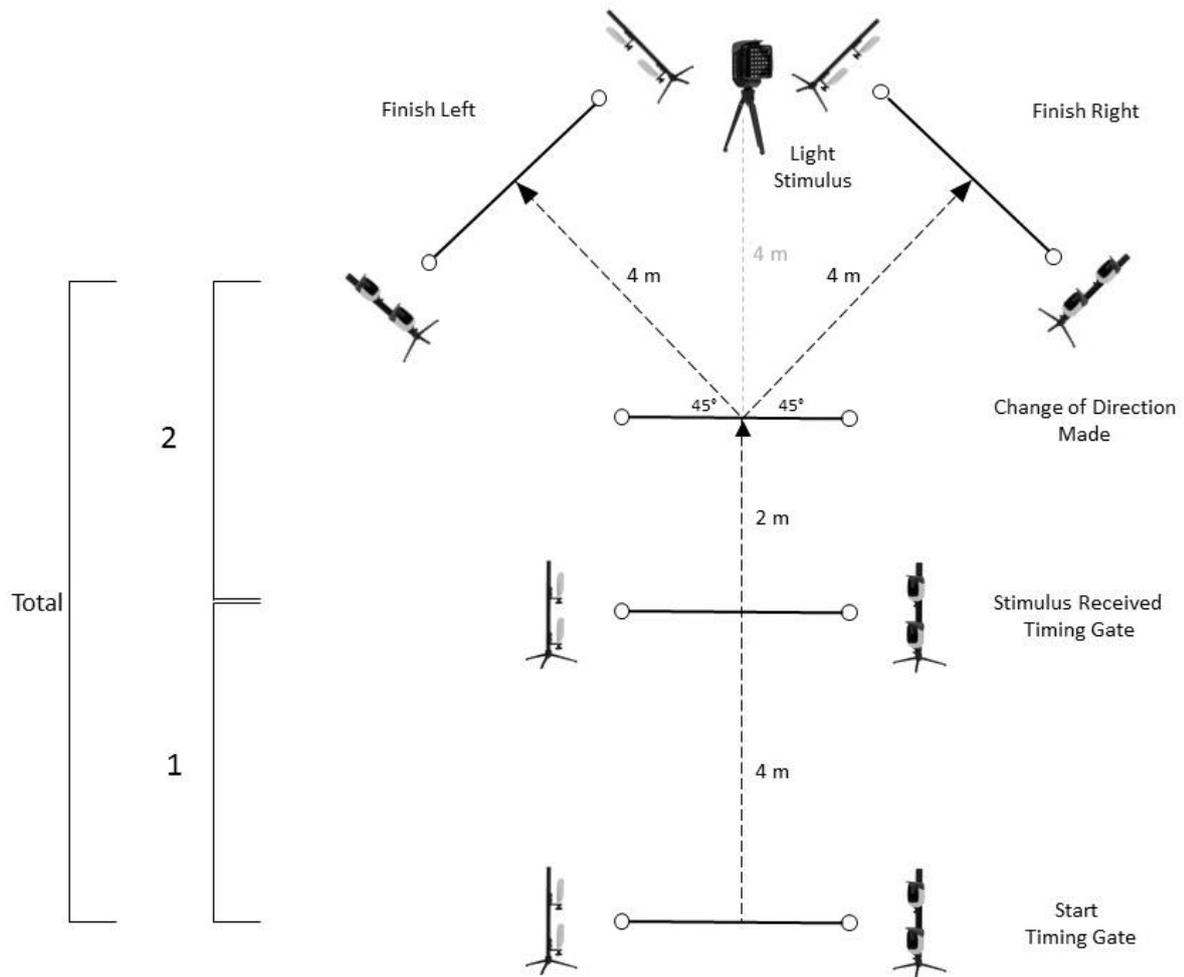


Figure 4.1 Layout and set up of the Y-Sprint drill for both PRE and REACT conditions. 1 = phase 1, 2 = phase 2, Total = total time.

Change of Direction Tests

Pre-planned change of direction ability through the horizontal plane was assessed via the m505COD test (Gabbett *et al.*, 2008). This methodology for the m505COD was as per originally established methods (Draper & Lancaster, 1985), however shortening the linear sprint by 5 m in distance. Therefore, this involved a 10 m linear sprint from a static start, a 180° turn on the nominated leg ensuring contact with a turn line, and a 5 m return sprint through an identified finish line. The combined duration of the final 5 m of the 10 m linear sprint, turn, and 5 m return sprint were recorded. COD performance was also assessed using a pre-planned version of the Y-Sprint drill (**Figure 4.1**) (Y-SprintPRE). Participants completed two attempts changing direction to the left and two attempts changing direction to the right. Best attempts from each direction were selected, mean times from these two attempts were calculated and used for analysis.

Agility Test

Agility performance was assessed using a reactive version of the Y-Sprint drill (Y-SprintREACT). The protocol for the Y-SprintREACT was identical to Y-SprintPRE trials, however with the addition of a Witty SEM light stimulus (Microgate, Bolzano, Italy), 10 m from the start position (**Figure 4.1**). Stimuli were displayed following a 0.5 s delay after crossing the 'stimulus received' timing gate and received in a randomised order, with four trials being completed for each participant. To account for performance variance during the Y-SprintREACT condition, the average of all four attempts was used for analysis (Al Haddad *et al.*, 2015; Oliver & Meyers, 2009). All participants completed the Y-SprintPRE trials prior to completing the Y-SprintREACT trials. Timings were provided for phase 1 (the initial 4 m linear sprint), phase 2

(the 2 m linear sprint followed by the change of direction), and a combination of both phases (total time) for both the Y-SprintPRE and Y-SprintREACT conditions.

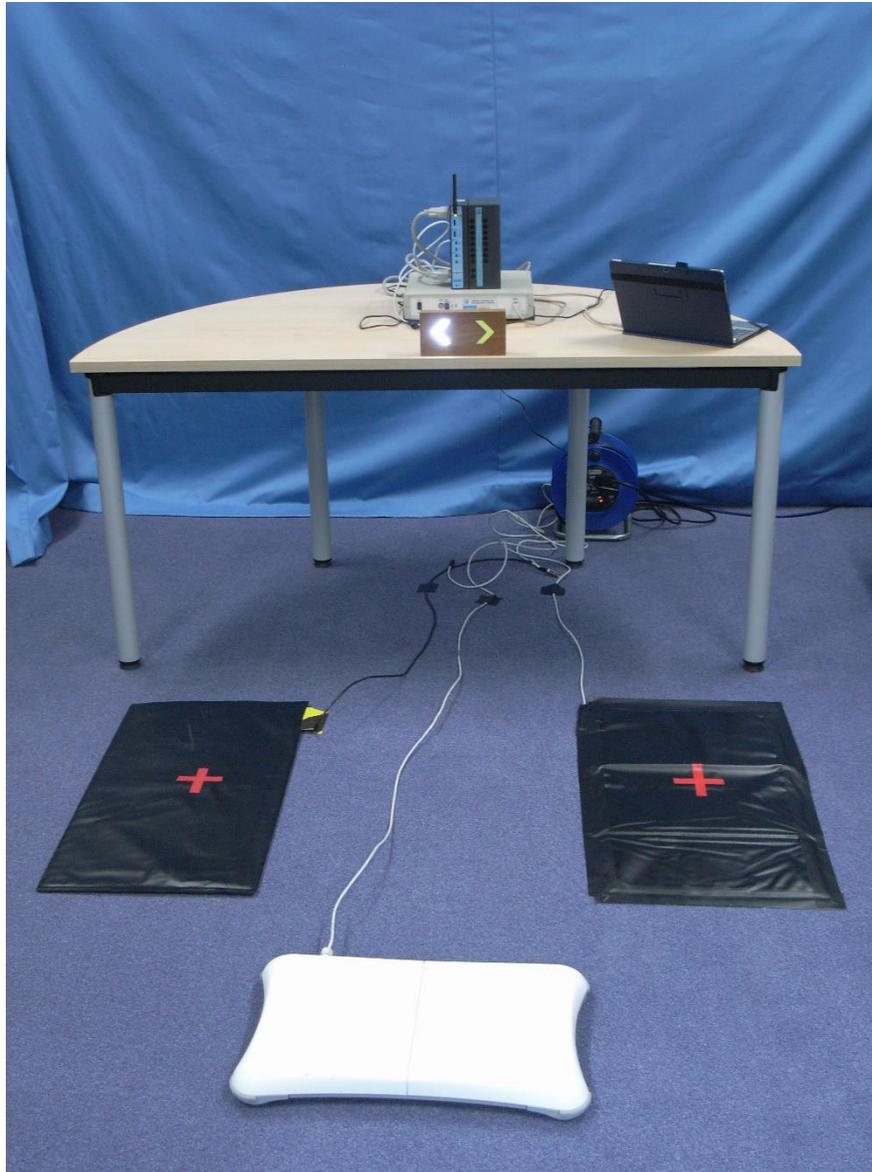


Figure 4.2. Layout and set up of the ‘complex’ version of the LBRTT (Spiteri et al., 2013).

Lower Body Reaction Time Test

The ‘complex’ version of the LBRTT established by Spiteri, Cochrane, & Nimphius (2013) was selected as a measure of reaction time within this study (**Figure 4.2**). Attempts for this test

required participants to stand on a custom-made force platform in an athletic 'ready' position with feet shoulder width apart. Participants were instructed to focus on a visual LED display positioned 1.5 m away from the force platform at a height of 1 m, remaining as still as possible. Two contact mats (PM2/PK, Defender Security, Leeds, UK) were used in conjunction with the force platform to test the foot reaction times of participants during the test. Contact mats were placed at 45° angles to the left and right, 70 cm in front of the force platform. Participants were instructed to leap from the force platform as fast as possible, landing with one foot in the centre of the contact mat in response to the visual stimulus, using the left foot to respond to the left-facing arrow and right foot when responding to the right-facing arrow. The visual stimulus was presented as an arrow on the LED display facing left or right, in a random order, appearing 3-5 s following the beginning of each attempt. Participants completed a total of 10 attempts, with each attempt starting automatically on a timed loop within the software. Attempts were collected over a period of 10 s and separated by a 10 s delay. The average of the 10 trials was used for analysis. Data for the LBRTT were analysed using AcqKnowledge v4.4 (Biopac Systems Inc, CA, USA). Response time (RT), movement time (MT), and total reaction time (TRT) were identified for each attempt of the LBRTT. RT was defined as the time taken from the presentation of the stimulus until a disturbance of >50N in force measured by the force platform was achieved. MT was defined as the time taken from the >50N disturbance on the force platform, to closing the switch on the appropriate contact mat. TRT was defined as RT + MT.

Statistical Analysis:

Prior to analysis, the assumption of normality was verified using the Shapiro-Wilk test. Age groups were compared via a one-way analysis of variance (ANOVA) with a Bonferroni post-

hoc test being implemented to identify differences between groups. A two-way random effects intra-class correlation coefficient (ICC), with absolute agreement and reporting 95% confidence intervals (95%CI), alongside the coefficient of variation (CV) was used to evaluate relative test-retest reliability. Standardised effect size, reported as Cohen's *d* using the pooled SD as the denominator, was calculated to evaluate the magnitude of the test-retest differences. As per guidelines provided by Atkinson & Nevill (1998) and Hopkins (2000) the tests were deemed as reliable if they met the following criteria: good-excellent ICC (≥ 0.80), good CV ($\leq 5\%$), and a trivial or small effect size (≤ 0.59). Comparisons between Y-SprintPRE and Y-SprintREACT tests were made using a paired-samples t-test, reporting Cohen's *d* effect size. Relationships between variables were assessed using Pearson's *r* correlation coefficient ($\pm 95\%$ CI). Interpretation of the strength of the correlation coefficients are based on guidelines provided by Hopkins (2002): 0-0.09 trivial; 0.1-0.29 small; 0.3-0.49 moderate; 0.50-0.69 large; 0.70-0.89 very large; 0.90-0.99 nearly perfect; 1.00 perfect. Linear association of relationships across age groups was assessed using Fisher's z-transformation. Statistical significance was set at $p \leq 0.05$.

4.3 Results

Descriptive performance measures

Higher test performance was observed for U13/U14 compared to U11/U12 players for all tests except the LBRTT(MT) ($p = 1.00$; $d = 0.04$), and for U15-U17 compared to U11/U12 players for all tests except the LBRTT(MT) ($p = 1.00$; $d = 0.06$) and Y-SprintREACT(2) ($p = 0.11$; $d = 0.36$) (**Table 4.1**). Differences were observed in the direction of U13/U14 < U15-U17 for the Y-SprintREACT(2) ($p < 0.01$; $d = 1.21$) (**Table 4.1**).

Reliability of COD/agility measures

Good between-day reliability was reported for the m505COD (ICC = 0.84-0.89), Y-SprintPRE (ICC = 0.87-0.91), and Y-SprinREACT (ICC = 0.81-0.86) for the age groups within our sample (**Table 4.2**). Notably, the COD/agility measures selected within this study demonstrated good reliability (ICC = 0.81-0.91; CV = 1.2-2.0; $d = 0.00-0.31$; $p < 0.01$) for all age groups. There was a small negative relationship observed between age and between-trial differences for Y-SprintPRE(Total) ($r = -0.28$; 95%CI: -0.07 – -0.47; $p = 0.04$), and moderate negative relationships observed between both age ($r = -0.41$; 95%CI: -0.20 – -0.60; $p < 0.01$), and APHV ($r = -0.39$; 95%CI: -0.20 – -0.58; $p < 0.01$) for Y-SprintREACT(Total) (**Table 4.3**).

Relationship between Y-SprintPRE and Y-SprintREACT conditions of the Y-Sprint drill

Performance during Y-SprintREACT(Total) was positively related to performance during Y-SprintPRE(Total) ($r = 0.67$ 95%CI: 0.53-0.77; $p < 0.01$) (**Figure 4.3A**), performance during Y-SprintREACT(1) was positively related to Y-SprintPRE(1) ($r = 0.83$; 95%CI: 0.76-0.88; $p < 0.01$)

Table 4.1 Anthropometric values and performance scores for all tests displayed by age group.

	U11/U12 (n=31)	U13/U14 (n=23)	U15-U17 (n=32)
Stature (cm)	148.0 ± 7.6	162.2 ± 9.4*	172.3 ± 9.5*†
Body mass (kg)	38.2 ± 6.1	49.5 ± 8.5*	62.1 ± 9.1*†
Seated height (cm)	77.8 ± 3.9	84.5 ± 5.0*	89.5 ± 5.4*†
Squat jump (cm)	37.1 ± 4.7	40.9 ± 5.3*	45.8 ± 4.9*†
CMJ (cm)	39.3 ± 5.0	45.3 ± 5.8*	50.3 ± 5.4*†
Grip strength (kg)	20.1 ± 4.0	27.5 ± 4.2*	40.0 ± 7.1*†
10m sprint (s)	1.99 ± 0.10	1.85 ± 0.09*	1.76 ± 0.07*†
40m sprint (s)	6.49 ± 0.43	5.86 ± 0.28*	5.38 ± 0.24*†
m505COD (s)	2.61 ± 0.14	2.43 ± 0.06*	2.33 ± 0.08*†
Y-SprintPRE(Total) (s)	1.98 ± 0.09	1.84 ± 0.07*	1.75 ± 0.07*†
Y-SprintPRE(1) (s)	0.92 ± 0.04	0.86 ± 0.04*	0.84 ± 0.05*
Y-SprintPRE(2) (s)	1.06 ± 0.05	0.99 ± 0.05*	0.91 ± 0.04*†
Y-SprintREACT(Total) (s)	2.54 ± 0.16	2.29 ± 0.12*	2.35 ± 0.15*
Y-SprintREACT(1) (s)	1.01 ± 0.06	0.92 ± 0.04*	0.86 ± 0.04*†
Y-SprintREACT(2) (s)	1.53 ± 0.12	1.37 ± 0.09*‡	1.49 ± 0.10
LBRTT(TRT) (s)	0.87 ± 0.09	0.78 ± 0.07*	0.78 ± 0.06*
LBRTT(RT) (s)	0.38 ± 0.08	0.29 ± 0.04*	0.28 ± 0.06*
LBRTT(MT) (s)	0.49 ± 0.09	0.49 ± 0.07	0.50 ± 0.06

Data are presented as mean ± standard deviation; n= sample size; * = significantly different to U11/U12; † = significantly different to U13/U14; ‡ = significantly different to U15-U17; all $p < 0.01$.

Table 4.2 Between-day test-retest reliability for COD and agility tests displayed by age group.

			U11/U12 (n=31)	U13/U14 (n=23)	U15-U17 (n=32)
Change of Direction	m505COD	Trial 1 (x ± SD) [s]	2.61 ± 0.14	2.43 ± 0.06	2.33 ± 0.08
		Trial 2 (x ± SD) [s]	2.60 ± 0.14	2.42 ± 0.11	2.34 ± 0.11
		ICC (95%CI)	0.88 (0.82-0.92)	0.84 (0.65-0.93)	0.89 (0.78-0.95)
		CV (%)	1.8	1.6	1.6
		<i>d</i>	0.07	0.11	0.10
	Y-SprintPRE	Trial 1 (x ± SD) [s]	1.86 ± 0.13	1.84 ± 0.07	1.75 ± 0.07
		Trial 2 (x ± SD) [s]	1.86 ± 0.12	1.83 ± 0.07	1.77 ± 0.06
		ICC (95%CI)	0.91 (0.87-0.94)	0.87 (0.72-0.94)	0.91 (0.82-0.95)
		CV (%)	1.5	1.2	1.4
		<i>d</i>	0.08	0.13	0.31
Agility	Y-SprintREACT	Trial 1 (x ± SD) [s]	2.40 ± 0.18	2.28 ± 0.12	2.35 ± 0.14
		Trial 2 (x ± SD) [s]	2.40 ± 0.18	2.29 ± 0.11	2.35 ± 0.15
		ICC (95%CI)	0.82 (0.59-0.92)	0.81 (0.55-0.92)	0.86 (0.71-0.93)
		CV (%)	2.0	1.7	1.7
		<i>d</i>	0.00	0.00	0.07

n = sample size; x ± SD = mean ± standard deviation; ICC = intra-class correlation, all $p < 0.01$; 95%CI = 95% confidence interval; CV = coefficient of variation; *d* = effect size

Table 4.3 Relationships between age/maturity offset and between-trial differences in performance for COD and agility tests.

	m505COD	Y-SprintPRE (Total)	Y-SprintREACT (Total)
Age (95%CI)	-0.14 (-0.10 - -0.36)	-0.28* (-0.07 - -0.47)	-0.41** (-0.20 - -0.60)
Maturity Offset (95%CI)	-0.19 (-0.03 - -0.39)	-0.19 (-0.01 - -0.38)	-0.39** (-0.18 - -0.57)

* $p < 0.05$; ** $p < 0.01$

(**Figure 4.3B**), and performance during Y-SprintREACT(2) was positively related to Y-SprintPRE(2) ($r = 0.48$; 95%CI: 0.30-0.63; $p < 0.01$) (**Figure 4.3C**). Performance during the Y-SprintPRE condition of the Y-Sprint drill was faster than the Y-SprintREACT condition during phase 1 (0.87 ± 0.06 s vs. 0.95 ± 0.07 s; $d = 1.07$; $p < 0.01$), phase 2 (0.99 ± 0.08 s vs. 1.46 ± 0.13 s; $d = 3.53$; $p < 0.01$), and total (1.86 ± 0.13 s vs. 2.40 ± 0.18 s; $d = 2.84$; $p < 0.01$).

Relationships between field-based fitness tests and Y-SprintREACT

Large to very large relationships (10m sprint, 40m sprint, m505COD, Y-SprintPRE(Total) – positive; CMJ, SJ – negative) were observed between our selected field-based fitness tests and Y-SprintREACT(Total), with exception of grip strength and LBRTT tests (**Figure 4.4A**). There were large to very large relationships observed between our selected field-based fitness tests and Y-SprintREACT(1) (10m sprint, 40m sprint, m505COD, Y-SprintPRE(Total) – positive; CMJ, SJ, grip strength – negative) (**Figure 4.4B**). Moderate to large relationships were observed between our selected field-based fitness tests and Y-SprintREACT(2) (10m sprint, 40m sprint, m505COD, Y-SprintPRE (Total) – positive; CMJ, SJ, grip strength – negative), with exception of the LBRTT (**Figure 4.4C**).

Positive relationships between 10m sprint, m505COD, Y-SprintPRE(Total) and Y-SprintREACT(Total) were observed across all age groups (**Table 4.4**). No phases of the LBRTT (RT, MT, TRT) demonstrated relationships across age groups to Y-SprintREACT(Total). Following Fisher's z-transformation of correlation coefficients, the Y-SprintREACT(Total) demonstrated stronger relationships between the 40m sprint for both the U11/U12 ($r = 0.71$; $p = 0.01$) and U13/U14 ($r = 0.71$; $p = 0.02$) group comparative to the U15-U17 ($r = 0.20$) group.

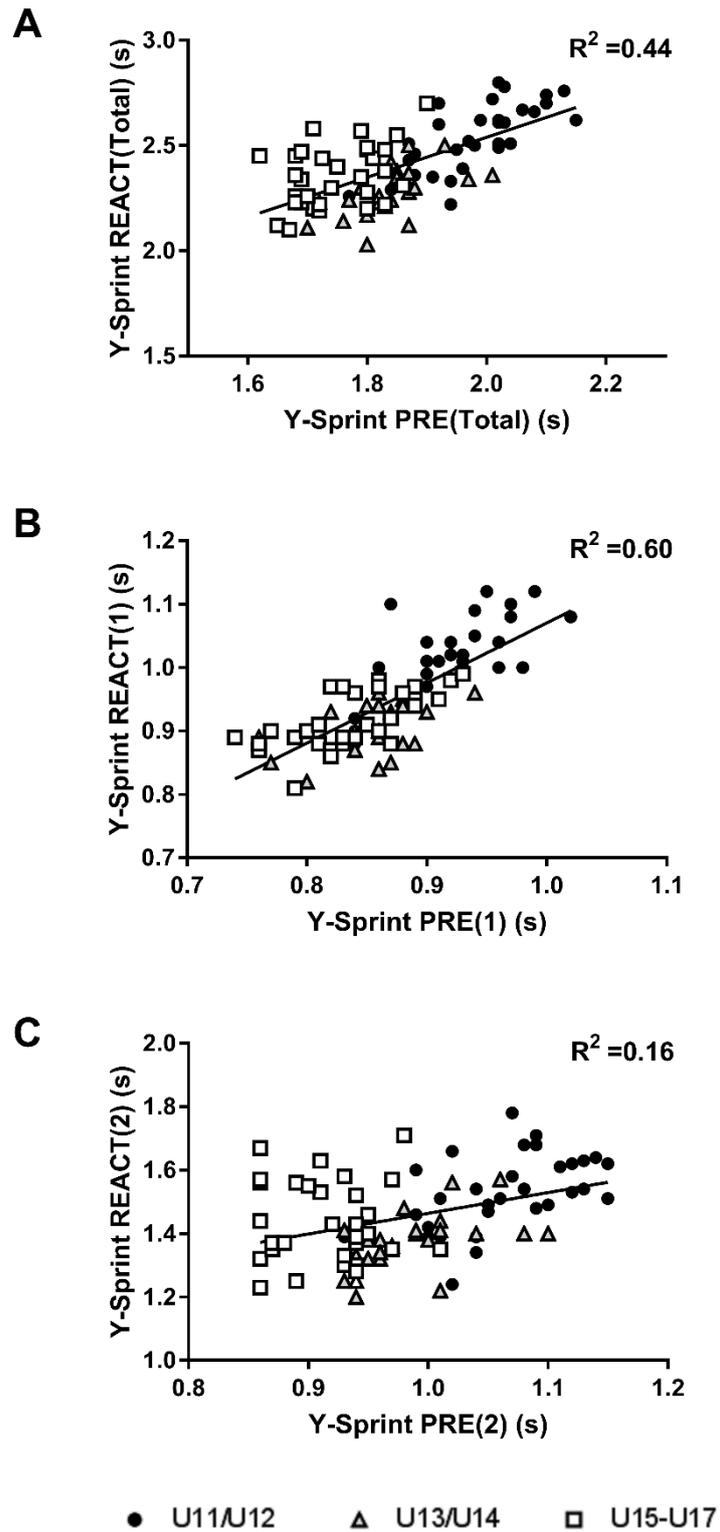
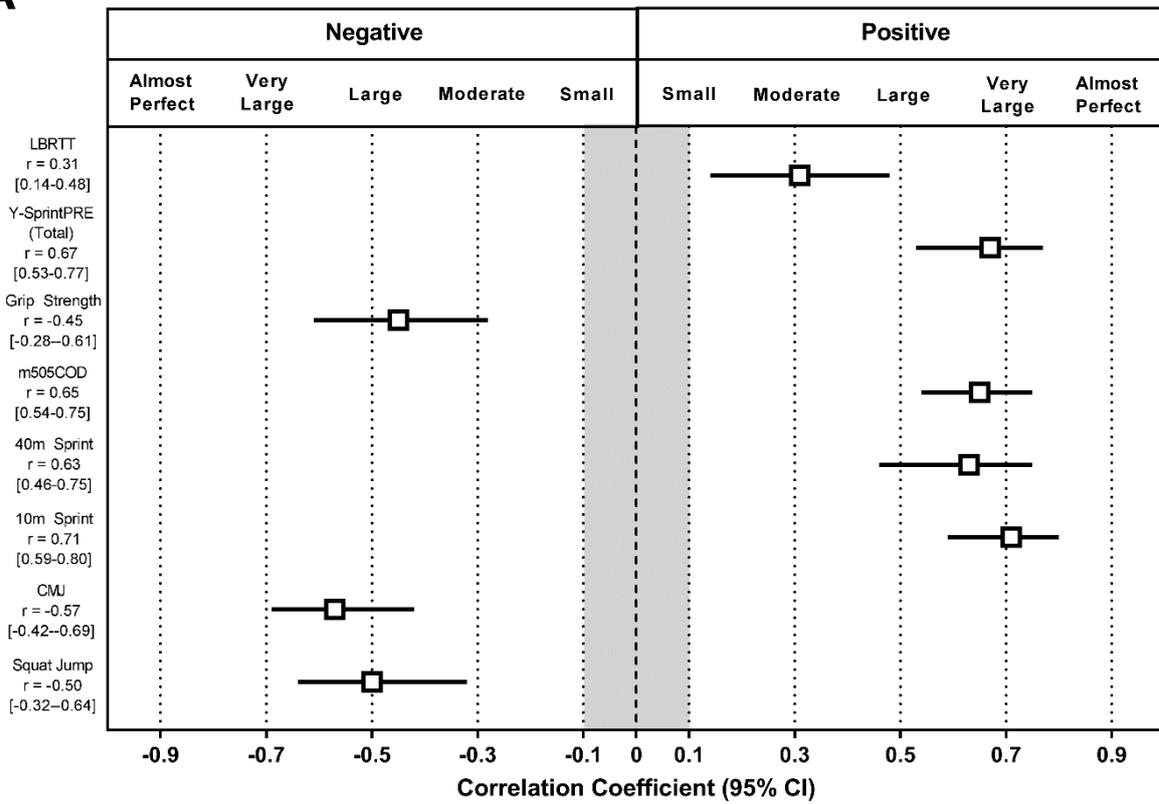
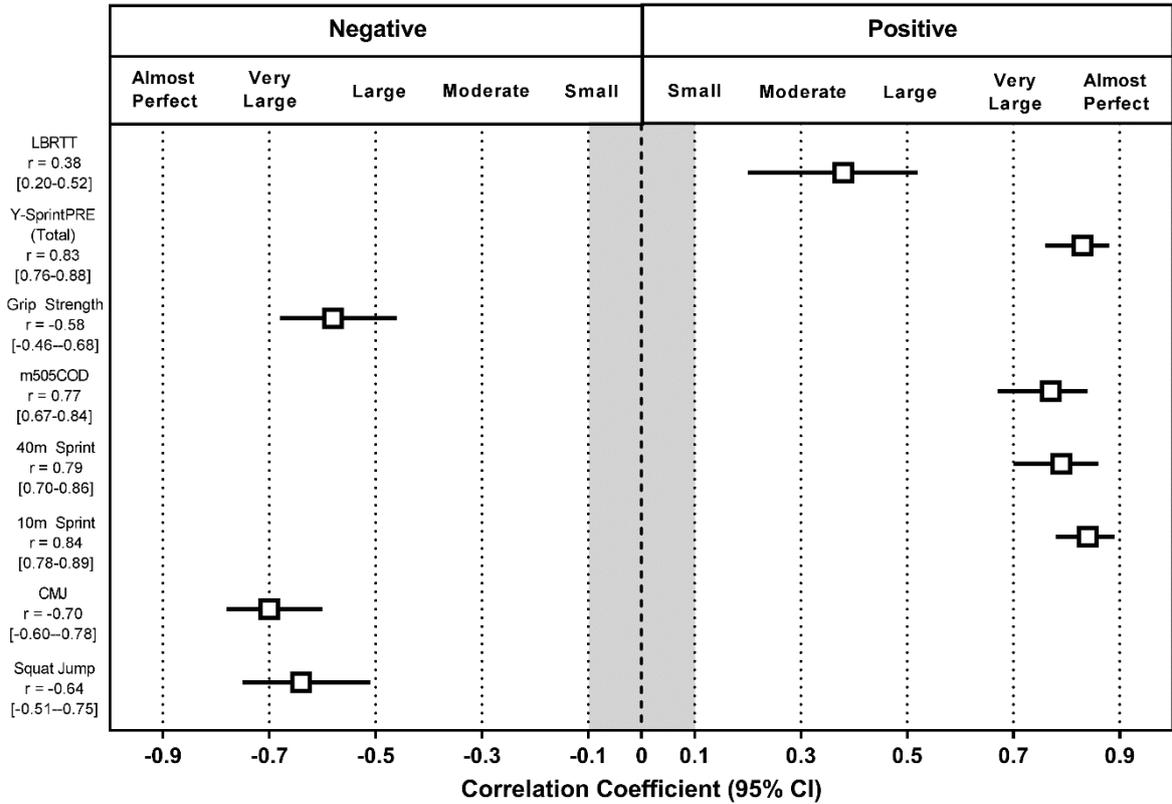


Figure 4.3 Relationship between PRE and REACT conditions of the Y-Sprint drill: **A** – Y-Sprint(Total); **B** – Y-Sprint(1); **C** – Y-Sprint(2).

A



B



C

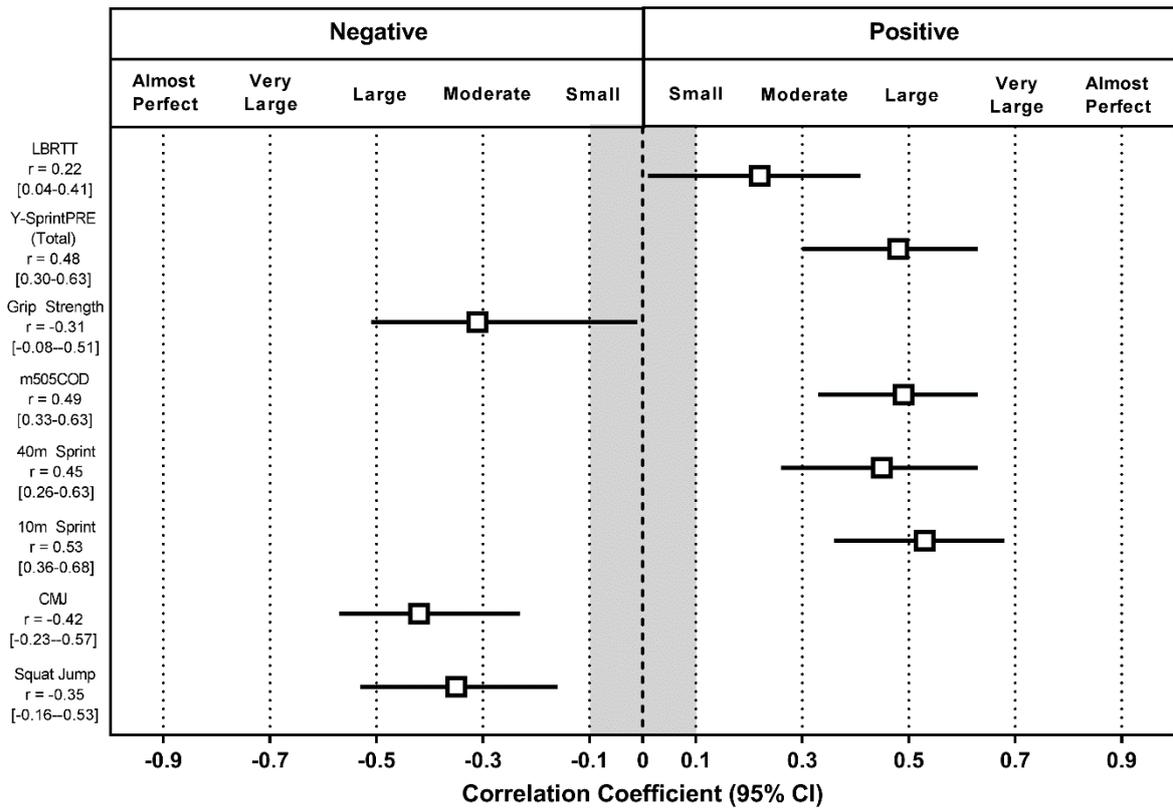


Figure 4.4 Relationships observed between fitness test variables and performance on: **A** – Y-SprintREACT(Total); **B** – Y-SprintREACT(1); **C** – Y-SprintREACT(2). Data are displayed as Pearson's r correlations \pm 95% confidence intervals.

Table 4.4 Relationships between fitness test variables and performance on the Y-SprintREACT(Total).

	U11/U12 (n=31)	U13/U14 (n=23)	U15-U17 (n=32)
SJ	-0.55** (-0.74 - -0.32)	-0.47* (-0.72 - -0.16)	-0.22 (-0.54-0.15)
CMJ	-0.55** (-0.73 - -0.36)	-0.39 (-0.71 - -0.06)	-0.42* (-0.68 - -0.05)
10m Sprint	0.71** (0.54-0.85)	0.77** (0.59-0.91)	0.54** (0.24-0.75)
40m Sprint	0.71** (0.53-0.86)	0.71** (0.45-0.86)	0.20 (-0.11-0.47)
m505COD	0.56** (0.37-0.76)	0.44* (0.08-0.72)	0.59** (0.28-0.79)
Grip Strength	-0.11 (-0.46-0.37)	-0.15 (-0.54-0.30)	-0.51** (-0.81 - -0.03)
Y-SprintPRE (1)	0.63** (0.41-0.80)	0.37 (0.10-0.62)	0.52** (0.20-0.75)
Y-SprintPRE (2)	0.67** (0.47-0.82)	0.60** (0.38-0.79)	0.13 (-0.29-0.46)
Y-SprintPRE (Total)	0.72** (0.55-0.85)	0.58** (0.38-0.76)	0.43* (0.04-0.72)
LBRTT (RT)	-0.09 (-0.39-0.24)	0.02 (-0.41-0.49)	0.13 (-0.33-0.49)
LBRTT (MT)	0.03 (-0.28-0.39)	0.21 (-0.38-0.59)	-0.11 (-0.43-0.31)
LBRTT (TRT)	-0.05 (-0.34-0.31)	0.22 (-0.36-0.65)	0.02 (-0.29-0.35)

Data are presented as correlation coefficients (95% confidence intervals); n=sample size; * $p < 0.05$, ** $p < 0.01$

4.4 Discussion

This study aimed to evaluate between-day reliability of COD/agility tests, and to examine relationships between associated physical and perceptual/decision making field-based fitness tests with an agility test across the entire spectrum of ages within a professional soccer academy. Main findings of the present study were: i) COD/agility tests proved reliable for all age groups; ii) measures of linear sprint and pre-planned COD ability related most to agility performance, with the LBRTT demonstrating the weakest relationship to agility performance across all phases and age groups, and; iii) strength of relationships observed between field-based fitness tests and the Y-SprintREACT drill remain relatively consistent across age groups.

Few studies have examined between-day reliability of COD test performance in youth athletes (Pojskic *et al.*, 2018; Young *et al.*, 2011), however, the COD tests examined within this study demonstrated better between-day reliability than previously observed for alternative COD tests within **Chapter 3** of this thesis. The stronger reliability demonstrated, could potentially be explained due to the high performance standard of our sample, previously proposed as an influencer of test reliability in adolescent athletes (Vandendriessche *et al.*, 2012; Vandorpe *et al.*, 2012). On the contrary, no influence on between-day test reliability was observed across 3 distinct performance standards of Scottish youth soccer players (**Chapter 3**). Considering the varied physical demands imposed by varied COD/agility tests (Pojskic *et al.*, 2018; Sporis *et al.*, 2010; Young *et al.*, 2015), implementation of alternative COD tests within the present study, may also explain observed differences in between-day reliability comparative to those observed in **Chapter 3**.

Whilst between-day reliability was acceptable across all age groups (**Table 4.2**), small to moderate negative relationships were observed between age/APHV and between-trial

performance differences for both Y-SprintPRE and Y-SprintREACT tests (**Table 4.3**). Although these relationships were small-to-moderate, this finding suggests that poor motor coordination, limited physical literacy, and underdeveloped strength capacities associated with less mature and chronologically younger athletes, may result in greater variability in test performance (Lloyd *et al.*, 2013; Vandendriessche *et al.*, 2012; Vandorpe *et al.*, 2012). Consequently, the requirement and suitability of COD/agility tests for the evaluation of young, immature athletic samples could be considered.

The greatest magnitude of difference, and least shared variance between PRE/REACT conditions of the Y-Sprint drill was observed during phase 2 (the reactive portion) of the test (**Figure 4.3C**). Prevalence of a stimulus during agility performance is reported to require a manipulation to body position, subsequently increasing the external loading on the knee when performing the cutting movement, thus contributing to an overall increase in movement time during the reactive condition of the Y-Sprint drill (Lee *et al.*, 2013). Moreover, an increase in cognitive processing time would have occurred to process and react to the provided stimulus of the Y-SprintREACT condition, further affecting overall test performance (Farrow *et al.*, 2005). Consequently, low percentage of shared variance observed between PRE/REACT conditions during phase 2 of the drill (upon presentation of the stimulus), supports the notion that COD and agility abilities are independent skills (Young, Dawson, & Henry, 2015).

Observed relationships between field-based fitness measures and the agility test adopted are substantially stronger than previously reported in senior team sport athletes (Gabbett *et al.*, 2008; Scanlan *et al.*, 2014; Sheppard *et al.*, 2006). Particularly, in the present study, large-very large relationships were reported between measures of jumping, linear sprint, and COD

abilities comparative to the Y-SprintREACT(Total) (**Figure 4.4A**). A potential explanation for the differences in relationship strength observed in the present study could be resultant of the study design, employing a generic light stimulus opposed to sport-specific. This form of stimulus removes abilities of performers to interpret subtle manipulations to body position and pattern recognition, prevalent during sport-specific scenarios, and subsequently placing greater demand on physical characteristics during agility task completion (Sheppard *et al.*, 2006). Despite this, use of commercially available light timing gate systems within an applied setting is extremely common. Therefore, knowledge provided by the present study may help better inform coaches and practitioners when using this equipment.

Interestingly, the LBRTT demonstrated the weakest relationship of all variables examined. It is rational that the generic light stimuli used for both the Y-SprintREACT and LBRTT within the present study resulted in weaker relationships than those adopting a more appropriate and sport specific stimulus. This discrepancy may, therefore, result in insignificant differences within the LBRTT, the measure of reaction time in the present study, and the Y-SprintREACT drill, thus increasing the prevalence by which physical abilities relate to agility performance in this study.

The strength of relationships observed were larger during phase 1 (**Figure 4.4B**), and smaller during phase 2 (**Figure 4.4C**) of the Y-SprintREACT drill for this sample. Relationships between the field-based fitness tests and agility performance also remained relatively stable across age groups during the Y-SprintREACT(Total). However, age group differences were observed by strength of relationship between 40m sprint performance and Y-SprintREACT(Total) (**Table 4.4**). Improved performance for 40m sprint test performance by the U15-U17 player group (**Table 4.1**) didn't translate into improved agility performance on the Y-SprintREACT(Total) for

this group. In fact, the U13/U14 group performed better than the U15-U17 group during phase 2 of the Y-SprintREACT drill, whilst the U13/U14 group were slower than the U15-U17 group during phase 1 of the Y-SprintREACT drill, the preceding phase of the Y-Sprint drill. It is proposed that, similar to the notions suggested by Nimphius, Callaghan, Spiteri, & Lockie (2016), absolute sprinting speed may not always relate to agility performance in youth soccer players. Consequently, by performing phase 1 of the Y-SprintREACT drill 'too quickly', individuals may potentially carry excess momentum into phase 2 of the drill, and both phase 2 of the Y-SprintREACT and total Y-SprintREACT performance may suffer.

4.5 Conclusion

This study is the first to examine relationships between a comprehensive battery of fitness tests and agility in a broad range of youth soccer players. These findings suggest that physical qualities (specifically short-distance linear sprint and pre-planned COD ability) relate strongly with agility performance within this sample, more so than previously reported in senior athletes. Moreover, the COD and agility tests adopted within this study possess good between-day reliability, which should therefore provide meaningful and objective data for monitoring development of youth soccer players. These findings identify physical qualities of importance for practitioners and researchers when aiming to improve and understand agility performance in youth soccer players.

IX – SYNTHESIS (CHAPTER 4 – CHAPTER 5)

Whilst **Chapters 3 & 4** developed methodological issues regarding physical fitness tests as part of the TI and TD process, the following experimental chapter (**Chapter 5**) will explore the role of subjective coaching opinion of physical qualities in youth soccer athletes. Findings from **Chapter 3** suggest that physical fitness tests are able to distinguish between distinct population groups (unidentified vs. identified), however, lack sensitivity to discriminate between more homogenous groups of identified players (development vs. performance). Despite and development of objective data and knowledge, discussions during **Section 2.1** establishes that subjective coach opinion continues to influence the TI process. Consequently, it would provide valuable information to coaches and practitioners to understand how objective performance on physical fitness tests align with coach perception of ability of physical characteristics during soccer training and competition. Similarly, considering that multiple coaches influence TI and TD processes during youth soccer players' careers, the subsequent chapter (**Chapter 5**) will also explore the agreement between two coaches when subjectively rating the same player on the same physical quality.

A better understanding of the relationship between these objective and subjective ratings will inform on the accuracy of coaches to rate physical abilities using subjective opinion.

CHAPTER 5

A COMPARISON OF OBJECTIVE AND SUBJECTIVE EVALUATION METHODS OF PHYSICAL QUALITIES IN PROFESSIONAL YOUTH SOCCER PLAYERS

Abstract

Subjective and objective assessments may be used congruently when making decisions regarding player selection/deselection and talent identification in soccer, yet there have been few attempts to examine whether these two types of judgements are related. We compare levels of agreement between subjective and objective assessments of physical qualities associated with elite soccer performance. Altogether, 80 male youth soccer players from six age groups (U11-U17 years), and 12 professional youth soccer coaches, a lead and assistant coach for each age group, volunteered to participate. Players were assessed objectively using six generic fitness/anthropometric measures: Yo-Yo Intermittent Recovery Test Level 1 (YYIRT L1); Countermovement vertical jump (CMJ); Functional Movement Screen™ (FMS); 5/20m sprint; and maturity offset derived from a maturity prediction equation. Additionally, coaches rated each player subjectively on the corresponding physical attributes using 5-point Likert scales. Inter-rater agreement between ratings provided by lead and assistant coaches were established for each age group. Moreover, Bayesian monotonic ordinal regression models were fitted to determine how well coach ratings for different physical qualities are able to predict fitness test performance. Although inter-rater agreement between the lead and assistant coach was moderate-substantial ($\omega = 0.48-0.68$) for physical qualities, relationships between coach subjective rating and a corresponding fitness test were accurate only for highest/lowest performers. We suggest that while ratings derived from objective and subjective assessment methods may be related when attempting to differentiate between distinct populations, concerns exist when evaluating homogeneous samples solely using subjective methods.

5.1 Introduction

Previous research, alongside findings from **Chapter 3** of this thesis, has demonstrated that physical performance measures can differentiate between distinct performance standards in groups of youth soccer players (Hulse *et al.*, 2013; Rebelo *et al.*, 2013; Reilly *et al.*, 2000), proving the value of including objective measures of physical fitness as part of TI. However, as previously discussed (**Section 2.1.1**), coaches and practitioners persist to subjectively influence decisions during the selection/deselection and TI process. Therefore, the requirement of strong levels of agreement between subjective and objective methods utilised within the TI and selection process is paramount for effective decision-making during selection/deselection processes and training prescription.

A select number of researchers have investigated the validity of coach-based assessments when evaluating performance in soccer. Larkin & O'Connor (2017) reported a range of technical, tactical, and psychological parameters perceived by experienced professional youth soccer coaches to be key attributes. These authors encourage the use of multi-disciplinary measures during the talent identification process, whilst acknowledging that physiological and anthropometrical qualities may be less important to coaches when selecting elite youth players. Hendry, Williams, and Hodges (2018) report physical ability to be an important contributing factor when players progress from youth to professional level. Also, the observation and assessment of simulated match performance has been publicised as an appropriate tool for talent identification and selection (Fenner *et al.*, 2016; Unnithan *et al.*, 2012). Within a cohort of pre-pubescent soccer players, very large relationships have been reported between subjective coach performance ratings and scoring metrics allocated during small-sided game performance (Fenner *et al.*, 2016). The validity of this method of assessment is supported by work from Morley *et al.* (2014), whose findings suggest that coach

opinion and ratings are dominated by perception regarding performance within training or game scenarios. Finally, Furley and Memmert (2016) propose that youth soccer coaches ground their conceptual thinking of sport giftedness within the perception of advanced maturity status. These authors suggest that physical stature and prominence influenced coach perception and rating, without evidence of any apparent performance advantage.

Accordingly, the purpose of this study was to: i) examine the inter-rater agreement between two coaches (lead vs. assistant) when rating youth soccer players on a range of physical abilities relative to successful soccer performance, and ii) examine the relationship between coach ratings for a range of physical abilities relative to successful soccer performance, and performance on a corresponding physical fitness test. It is hypothesised that subjective coach rating relates with objective physical performance on corresponding physical fitness tests, however, discrepancies in the agreement between these two methods may exist. It is also hypothesised that there will be some agreement between the two coaches when rating players' physical abilities, however, the extent of this agreement may vary between characteristics.

5.2 Methods

Participants:

Players

Eighty male youth soccer players (mean \pm SD [range]: age 13.2 ± 1.9 [10.2-16.7] years; stature 160.3 ± 13.9 [130.1-185.3] cm; mass 49.3 ± 12.4 [27.4-83.7] kg) volunteered to participate in this study. All participants were signed to a professional soccer academy playing at the highest competitive level of youth soccer within Scotland. Participants were categorised within the following age groups as specified by the Scottish Football Association (SFA): U11 (n=16), U12 (n=14), U13 (n=11), U14 (n=12), U15 (n=12) and U17 (n=15). Prior to conducting any trials, participant and parental/guardian consent was gained alongside providing comprehensive written and oral explanations about the study. The study received institutional ethical approval.

Coaches

Twelve male youth soccer coaches additionally volunteered to participate in this study. A lead and assistant coach were assigned to each of the 6 age groups listed above, with both coaches being recruited for the study. Lead coaches had (mean \pm SD [range]): 13.5 ± 5.7 [6.25-20.0] years coaching experience; 1.8 ± 1.4 [0.5-4.0] years coaching history with their current team; and held either the SFA Advanced Children's or the UEFA Youth A licence coaching qualifications. Assistant coaches had (mean \pm SD [range]): 13.3 ± 6.5 [4.0-20.0] years coaching experience; 1.3 ± 0.8 [0.5-2.0] years coaching history with their current team. Coaching qualifications held by assistant coaches ranged from no formal coaching qualification to holding the UEFA Youth B licence coaching qualification.

Procedures:

Data were collected from the YYIRT L1, CMJ, Functional Movement Screen™ (FMS), 5m and 20m linear sprint tests, alongside anthropometric measures of body mass, stature, and seated height. The fitness tests selected have previously been reported as common physical performance measures within youth soccer (Paul & Nassis, 2015a). Selected tests were identified to be appropriate for implementation across the entire age range of the selected sample, and relevant to the physical demands of soccer (Paul & Nassis, 2015a). Testing sessions were completed a minimum of 48hours following a competitive game, and in absence of strenuous exercise within 24hours prior. Testing sessions were conducted indoors (~22°C) on a non-slip sports hall playing surface. Participants conducted a standardised warm-up protocol consisting of light aerobic activity, dynamic stretching, and progressive sprinting. Following the standardised warm-up, participants received verbal instruction and demonstrations from the research team immediately prior to conducting 2-3 familiarisation attempts for each test. When required, guidance and feedback were provided to participants by the research team following each familiarisation attempt, however no guidance was provided to participants between recorded attempts. For tests where electronic timing gates were used, gates were adjusted to an appropriate height as per the mean stature of the sample group, and start positions were standardised as a fixed-position crouch start from 1m behind the start gate (Haugen & Buchheit, 2016). Data were collected using the Brower TC Timing System (Brower Timing Systems, Draper, UT). Participants completed 3 attempts of each test (unless otherwise stated) with the best attempt being selected for analysis. Recovery intervals between attempts were standardised at 3 minutes for each test.

Measures:

Anthropometrics/Maturity Status

Standing stature and sitting height was assessed using a free-standing stadiometer (Seca, Birmingham, UK) and body mass was assessed using digital floor scales (Seca, Birmingham, UK). Somatic maturity estimates were made for all participants via non-invasive methods. A regression equation was used to estimate years from age at peak height velocity (maturity offset) (Mirwald *et al.*, 2002). Calculations required standing stature, sitting height, and mass values described above, alongside chronological age at the time of measurement.

Yo-Yo Intermittent Recovery Test Level 1 (YYIRT L1)

The YYIRT L1 was conducted according to methods outlined by (Krustrup *et al.*, 2003). Participants were instructed to perform the test to exhaustion and were withdrawn from the test following two consecutive failures to reach the finishing line in time. The distance covered during the test was recorded in metres and represents the finishing level of the test. Participants were familiarised to the test by at least one pre-test (Doncaster, Scott, *et al.*, 2018; Enright *et al.*, 2017).

Countermovement Vertical Jump (CMJ)

CMJ data were collected using the Just Jump mat (Probiotics, Huntsville, AL). Attempts were conducted adopting the arms akimbo position and utilising a self-selected countermovement depth. Attempts were disqualified if participants abandoned the arms akimbo position or actively flexed at the knee or hip during flight. CMJ was measured to the nearest 0.1cm reported via the Just Jump handheld unit.

Functional Movement Screen™ (FMS)

Participants were screened using the FMS protocol comprised of the following seven movement patterns: deep overhead squat, in-line lunge, hurdle step, active straight leg raise, trunk stability push-up, shoulder mobility, and rotary stability. As per the movement screen testing guidelines (Cook, Burton, & Hoogenboom, 2006), participants were given three trials of each movement pattern, with each trial being scored by a team of experienced raters (~2 years' experience of screening) on a 4-point scale ranging from 0 (participant has pain anywhere in the body at any time during the test) to 3 (participant is able to perform the movement correctly without compensation). The highest score from the three trials was recorded, however in instances where the movement pattern was performed separately on the right and left sides, the lower of the two scores was recorded. The combined points total of the seven exercises was used for analysis.

Linear Sprint (5/20m)

Linear acceleration and sprinting speed was assessed over distances of 5/20m as per previously reported match-based observations of youth soccer players (Buchheit et al., 2010).

Subjective ratings

Coaches used a 5-point scale (1 = poor to 5 = excellent) to rate the physical abilities of each player relative to other players at an age and skill-appropriate level. Such coach-based ratings have been adopted in previous research demonstrating good reliability and validity (Ali, 2011; Hendry, Williams, & Hodges, 2018; Larkin & O'Connor, 2017; Unnithan *et al.*, 2012). Both the lead and assistant coach for each age group provided ratings for players from their squad at identical time points and using an identical scale. The physical abilities rated by the coaches

were selected as the qualities intended for assessment by the physical fitness tests: 'Endurance' – YYIRT L1 (Krustrup *et al.*, 2003); 'Power' – CMJ (Paul & Nassis, 2015b); 'Movement Quality' – FMS™ (Lloyd *et al.*, 2015); 'Physical Development' – maturity offset (Mirwald *et al.*, 2002); 'Acceleration' – 5m linear sprint (Sporis *et al.*, 2009); and 'Sprint Speed' – 20m linear sprint (Sporis *et al.*, 2009). Coaches completed the rating scales before a regular scheduled training session, and at least 48hours following a competitive game to minimise bias from the players' most recent match performance. Rating scales were completed the week prior to players completing the fitness testing battery and were completed independently without confirmation with other coaches or support staff.

Statistical Analysis:

Descriptive statistics of physical test performance associated with lead and assistant coach ratings of corresponding subjective qualities are presented as means \pm standard deviations (SD). Inter-rater agreement between the lead and assistant coach is reported as Sklar's ω and interpreted as: ($\omega \leq 0.2$) – slight agreement; ($0.21 < \omega \leq 0.4$) – fair agreement; ($0.41 < \omega \leq 0.6$) – moderate agreement; ($0.61 < \omega \leq 0.8$) – substantial agreement; ($\omega > 0.81$) – near-perfect agreement (Hughes, 2018). A series of Bayesian regression models were fitted to determine how well coach ratings are able to predict performance in measures assessing corresponding physical qualities. Leave-One-Out cross-validation (LOO) was used to determine the best model for predicting relationships between ratings and measured variables. The best models, those with the lowest LOO information criterion, were Bayesian monotonic ordinal regression models. Bayesian monotonic ordinal regression models allow ordinal predictors to be modelled without falsely treating them either as continuous or as unordered categorical predictors, allowing predictors to be non-equidistant with respect to their relationship to a

response variable. For example, coaches ratings on a 5-point scale (1 = poor to 5 = excellent) cannot be considered interval level values. While they have a meaningful order, the intervals between ratings may be uneven. Therefore, while a rating of four is higher than a rating of one, two or three, it is not twice the value of two. Treating ordinal ratings as if they were on an interval scale can lead to inaccurate predictions and inaccurate relationships. Bayesian monotonic ordinal regression models allow ordinal predictors to be modelled appropriately without falsely treating them either as continuous variables or as unordered categorical predictors. Estimates from the models are presented along with 95% credible intervals and associated simplex parameters. All analyses were conducted using R (R Core Team).

Explanation of output

In the example output (**Table 5.1**), the Intercept (1) relates to the metres covered on the YYIRT L1 rated 1 (poor) by the coach. The b coefficient captures the entire range of coach ratings (1 poor – 5 excellent). The simplex parameters (2 – 5) represent the distance between ratings and can be considered as simple percentages of the difference when multiplied by 100. To explore predicted values, we start with the intercept (prediction at rating of 1), then multiplying the simplex parameters with the b coefficient and summing these for each level. A visual representation of this data is provided in **Figure 5.1**.

Table 5.1 Example output from a monotonic regression model predicting distance covered on the YYIRT L1 by coach rating at population level.

		Effects			Simplex Parameters		
		Intercept (1)	b	2	3	4	5
YYIRT L1 (m)	Estimate	1118.9	1031.5	0.13	0.15	0.43	0.29
	Estimated Error	163.4	261.3	0.11	0.11	0.16	0.16
	Lower 95% CI	750.2	564.7	0.01	0.01	0.13	0.02
	Upper 95% CI	1395.8	1580.9	0.39	0.41	0.75	0.61

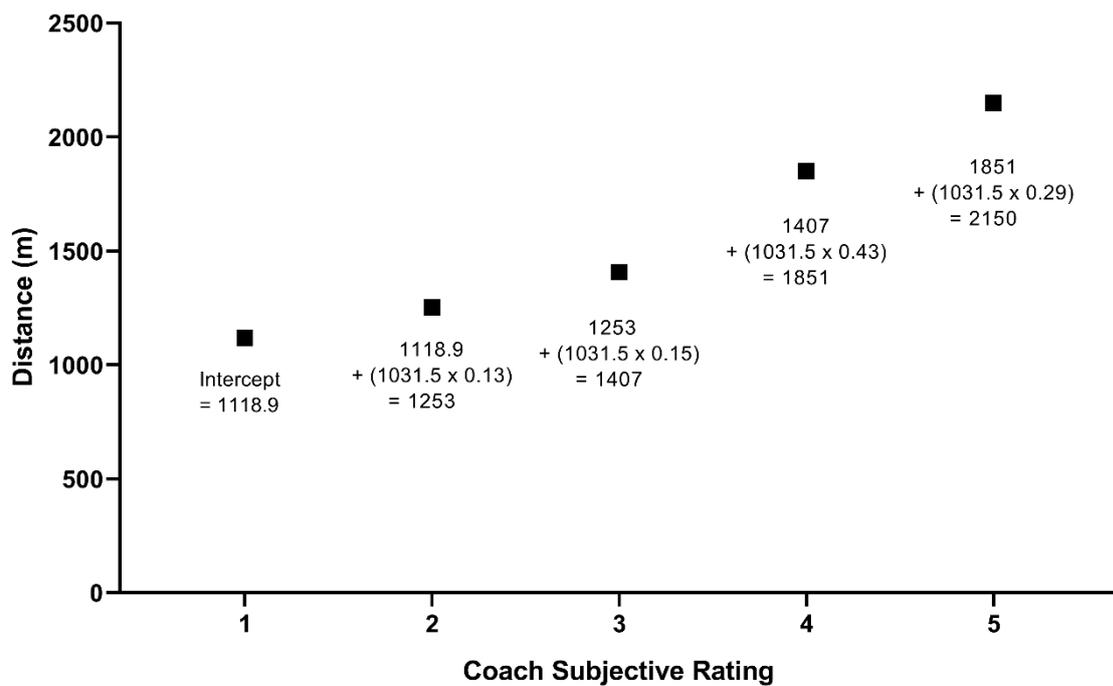


Figure 5.1 A visual example of calculations applied for coach ratings 1 to 5 from the monotonic regression model.

5.3 Results

Inter-rater reliability of coach subjective ratings

The lead and assistant coach ratings displayed moderate-substantial agreement when rating players' physical abilities on a 5-point rating scale (**Table 5.2**). Levels of agreement between the lead and assistant coaches ranged from: $\omega = 0.48$ (moderate) for 'Endurance'; to: $\omega = 0.68$ (substantial) for 'Power'.

Table 5.2 Sklar's ω for the level of agreement of the ratings between the lead coach and assistant coach.

Quality rated	Sklar's ω	Descriptive interpretation
Endurance	0.48	Moderate
Power	0.68	Substantial
Movement Quality	0.49	Moderate
Physical development	0.54	Moderate
Acceleration	0.62	Substantial
Speed	0.62	Substantial

Inter-rater accuracy of ratings

Lead coach's ratings explained a higher percentage of variance in performance variables across models than those awarded by the assistant coach (**Table 5.3**). Variance explained differed depending on the quality rated. The highest variance explained was the lead coach's ratings for endurance which explained 23% of the variance in the YYIRT L1. The lowest variance explained was 1% of the variance in movement quality, explained by the assistant

Table 5.3 A Bayesian estimation of the coefficient of variation (R^2) with 95% credible intervals for each of the Bayesian monotonic ordinal regression models.

		Endurance	Power	Movement Quality	Physical Development	Acceleration	Sprint Speed
Lead Coach	R^2	0.23	0.11	0.05	0.03	0.17	0.20
	95% CI	0.08-0.37	0.01-0.23	0.00-0.16	0.00-0.12	0.04-0.32	0.06-0.33
Assistant Coach	R^2	0.03	0.09	0.01	0.02	0.06	0.07
	95% CI	0.00-0.11	0.00-0.22	0.00-0.07	0.00-0.08	0.00-0.18	0.00-0.19

coach's ratings of physical development (**Table 5.3**). The lead coach's highest ratings equated to the best performances for YYIRT L1, CMJ, FMS, 5m and 20m sprint. The lowest ratings awarded by the lead coach equated to the poorest performances for CMJ, 5m and 20m sprint. However, the only variable where the lead coach's progressively higher ratings align with a progressively better mean performance was for CMJ performance. The assistant coach's highest ratings equated to the best performances for CMJ, 5m and 20m sprint, and the lowest ratings to the poorest performances for YYIRT L1, FMS and 5m sprint. Nonetheless, the only variable where mean performances increase with progressively higher ratings by the assistant coach is for 5m sprint performance (**Table 5.4**).

Predictive ability of coach subjective ratings relative to fitness test performance

Visual inspection shows the data is skewed for different rating categories across measures (**Figure 5.2**). The marginal effects for the Bayesian monotonic ordinal regression models show that the ratings by both the lead and assistant coach have nonlinear relationships with the measured variables predicted (**Figure 5.3**).

The Bayesian monotonic ordinal regression models show the ratings awarded by both the lead and assistant coaches are not evenly assigned. If ratings for each of the performance qualities were equidistant, 25% of the difference would be captured between each rating 1 to 5. However, the simplex parameters for each of the models suggest the distance between the ratings varies across each of the performance qualities and between coaches: lead coach (**Table 5.5**) and assistant coach (**Table 5.6**). The lowest difference, 11% found between ratings

Table 5.4 Descriptive statistics of raw data from measured variables for coach's ratings of players' corresponding physical abilities.

		Coach's Subjective Rating				
		1 Poor	2 Below Average	3 Average	4 Above Average	5 Excellent
YYIRT L1 (m)	Lead	1387 ± 167 (n = 3)	1213 ± 551 (n = 16)	1374 ± 566 (n = 29)	1855 ± 577 (n = 24)	2234 ± 621 (n = 7)
	Assistant	920 ± 396 (n = 2)	1184 ± 409 (n = 5)	1613 ± 501 (n = 22)	1667 ± 711 (n = 41)	1329 ± 615 (n = 9)
CMJ (cm)	Lead	40.4 ± 5.2 (n = 3)	40.7 ± 5.7 (n = 14)	42.2 ± 7.7 (n = 33)	45.9 ± 7.1 (n = 23)	48.9 ± 5.6 (n = 6)
	Assistant	42.3 ± N/A (n = 1)	39.3 ± 3.7 (n = 9)	41.9 ± 7.2 (n = 33)	45.6 ± 7.3 (n = 24)	46.4 ± 7.8 (n = 12)
FMS (score)	Lead	16.3 ± 2.1 (n = 4)	15.8 ± 2.7 (n = 16)	17.0 ± 1.9 (n = 34)	17.2 ± 2.5 (n = 20)	17.6 ± 0.9 (n = 5)
	Assistant	15.5 ± 2.1 (n = 2)	16.5 ± 2.4 (n = 12)	17.3 ± 2.2 (n = 24)	16.5 ± 2.6 (n = 27)	16.9 ± 1.5 (n = 14)

Table 5.4 Cont.

		Coach's Subjective Rating				
		1 Poor	2 Below Average	3 Average	4 Above Average	5 Excellent
Maturity offset (years)	Lead	-1.9 ± 1.6 (n = 6)	-2.4 ± 0.8 (n = 13)	-2.4 ± 1.1 (n = 30)	-1.8 ± 1.5 (n = 22)	-1.8 ± 1.3 (n = 8)
	Assistant	-1.3 ± 2.6 (n = 2)	-2.4 ± 1.0 (n = 6)	-2.3 ± 1.1 (n = 34)	-1.9 ± 1.4 (n = 18)	-2.2 ± 1.3 (n = 19)
5m sprint (s)	Lead	1.14 ± 0.05 (n = 7)	1.06 ± 0.11 (n = 10)	1.06 ± 0.08 (n = 36)	1.03 ± 0.08 (n = 22)	0.94 ± 0.07 (n = 4)
	Assistant	N/A	1.09 ± 0.06 (n = 14)	1.05 ± 0.10 (n = 34)	1.03 ± 0.08 (n = 28)	1.02 ± 0.11 (n = 5)
20 sprint (s)	Lead	3.50 ± 0.15 (n = 7)	3.30 ± 0.29 (n = 10)	3.34 ± 0.19 (n = 36)	3.18 ± 0.21 (n = 22)	3.01 ± 0.17 (n = 4)
	Assistant	3.31 ± 0.02 (n = 2)	3.45 ± 0.13 (n = 7)	3.33 ± 0.26 (n = 28)	3.24 ± 0.21 (n = 35)	3.21 ± 0.25 (n = 7)

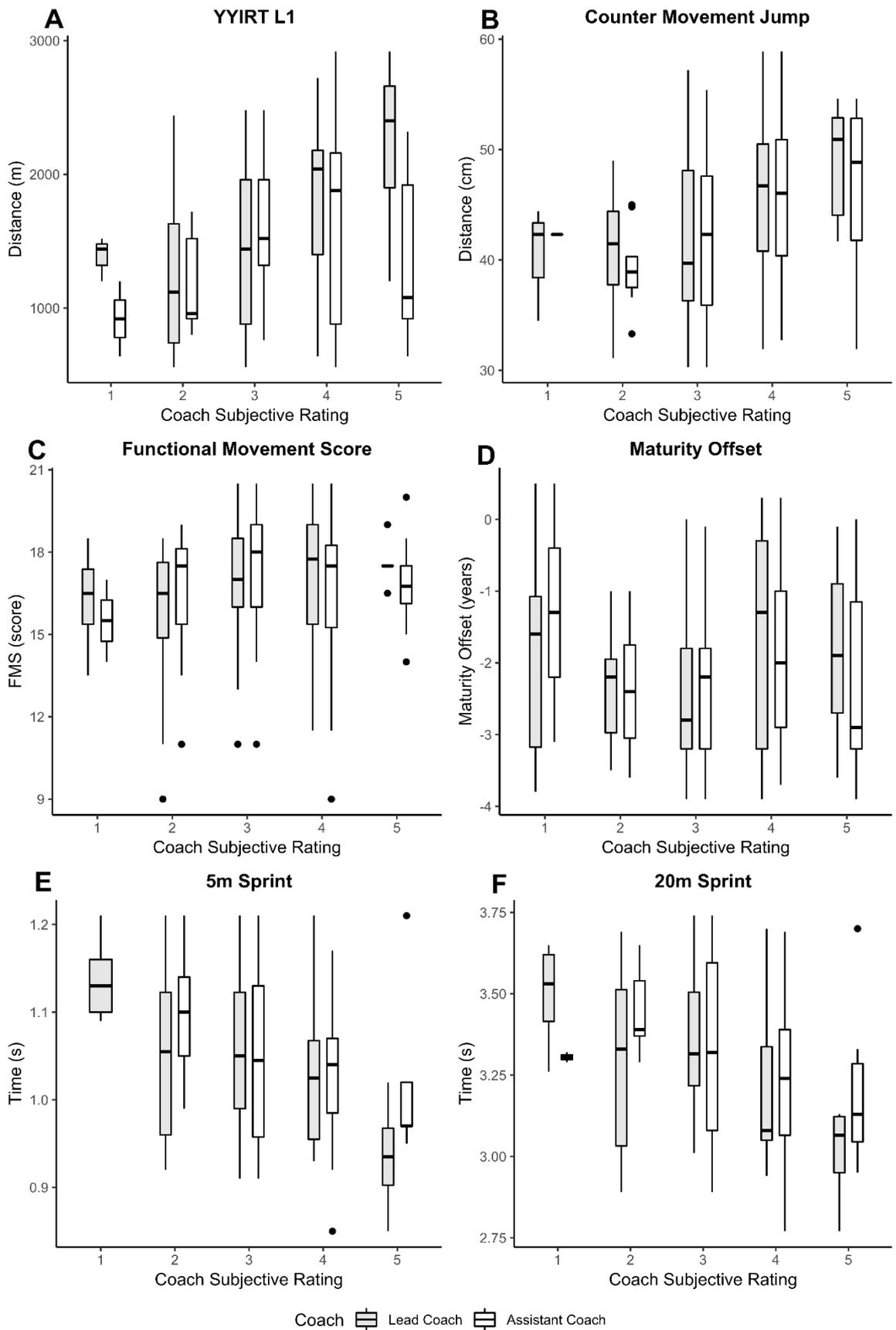


Figure 5.2 Raw data boxplots for lead and assistant coach ratings for: **A)** Yo-Yo test distance; **B)** CMJ height; **C)** FMS score; **D)** maturity offset years; **E)** 5m sprint times, and; **F)** 20m sprint times.

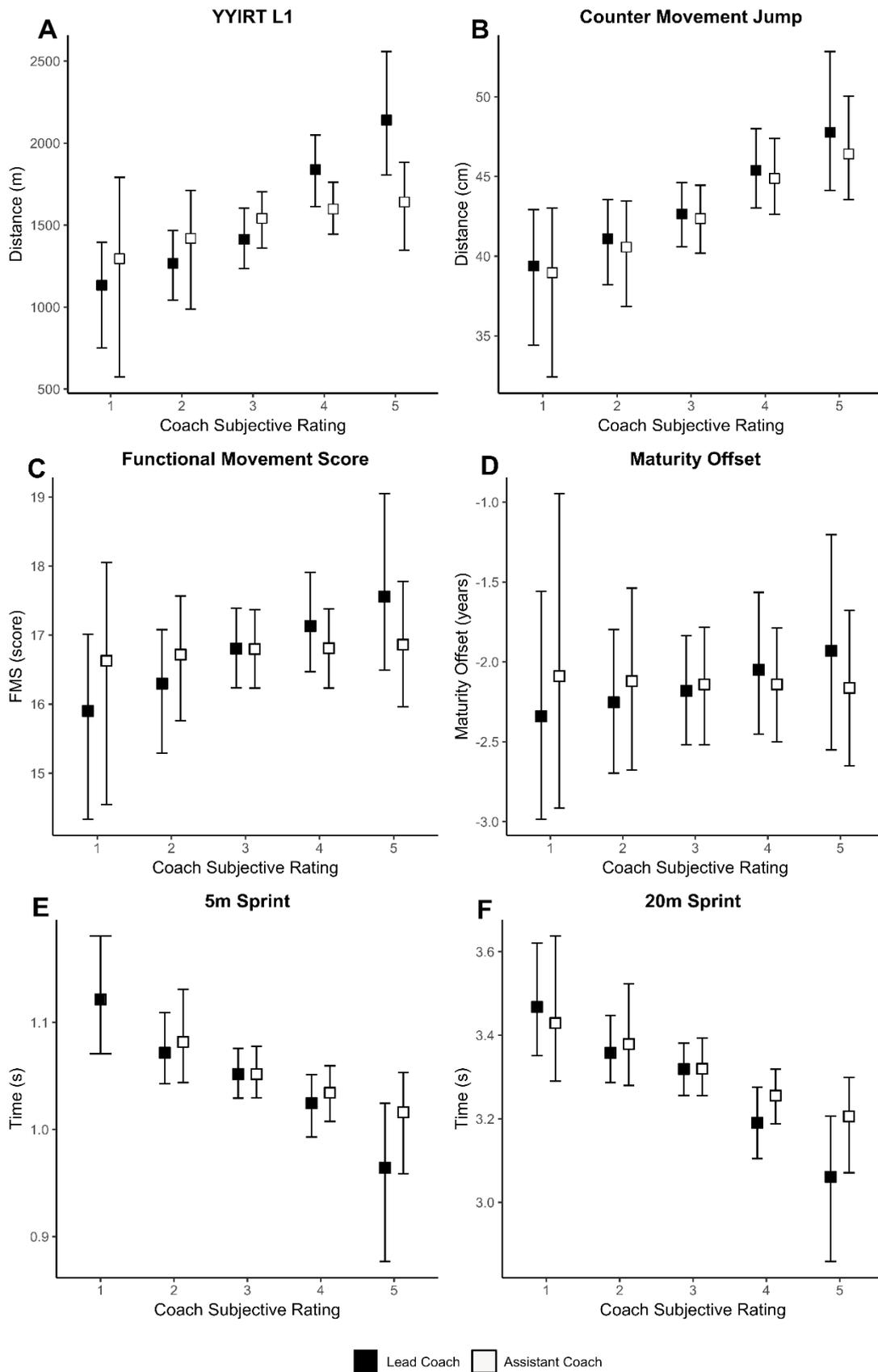


Figure 5.3 Marginal effects of the predictive Bayesian monotonic ordinal regression models ($\pm 95\%CI$) for lead and assistant coach ratings at population level for: **A**) Yo-Yo test distance; **B**) CMJ height; **C**) FMS score; **D**) maturity offset years; **E**) 5m sprint times, and; **F**) 20m sprint times.

Table 5.5 Coefficients, simplex parameters and 95% credible intervals for Bayesian monotonic ordinal regression models for performance measures predicted by the ratings of lead coach.

		Effects			Simplex Parameters		
		Intercept (1)	b	2	3	4	5
YYIRT L1 (m)	Estimate	1118.9	1031.5	0.13	0.15	0.43	0.29
	Estimated Error	163.4	261.3	0.11	0.11	0.16	0.16
	Lower 95% CI	750.2	564.7	0.01	0.01	0.13	0.02
	Upper 95% CI	1395.8	1580.9	0.39	0.41	0.75	0.61
CMJ (cm)	Estimate	39.2	8.8	0.20	0.19	0.33	0.28
	Estimated Error	2.1	3.3	0.15	0.14	0.18	0.17
	Lower 95% CI	34.4	2.8	0.01	0.01	0.03	0.01
	Upper 95% CI	42.9	15.8	0.56	0.52	0.73	0.64
FMS (score)	Estimate	15.6	1.8	0.22	0.31	0.21	0.26
	Estimated Error	0.7	1.1	0.17	0.19	0.17	0.19
	Lower 95% CI	14.3	-0.3	0.01	0.02	0.01	0.01
	Upper 95% CI	17.0	4.1	0.65	0.71	0.63	0.68
Maturity offset (years)	Estimate	-2.3	0.4	0.23	0.22	0.29	0.27
	Estimated Error	0.4	0.6	0.19	0.17	0.21	0.19
	Lower 95% CI	-3.0	-0.8	0.01	0.01	0.01	0.01
	Upper 95% CI	-1.6	1.5	0.68	0.64	0.74	0.71
5m sprint (s)	Estimate	1.1	-0.2	0.30	0.14	0.19	0.37
	Estimated Error	0	0.1	0.16	0.11	0.13	0.17
	Lower 95% CI	1.1	-0.3	0.03	0.00	0.01	0.04
	Upper 95% CI	1.2	-0.1	0.63	0.43	0.49	0.69
20m sprint (s)	Estimate	3.5	-0.4	0.26	0.11	0.33	0.31
	Estimated Error	0.1	0.1	0.15	0.09	0.15	0.16
	Lower 95% CI	3.4	-0.7	0.02	0.00	0.07	0.03
	Upper 95% CI	3.6	-0.2	0.57	0.34	0.66	0.63

Table 5.6 Coefficients, simplex parameters and 95% credible intervals for Bayesian monotonic ordinal regression models for performance measures predicted by the ratings of assistant coach.

		Effects			Simplex Parameters		
		Intercept (1)	b	2	3	4	5
YYIRT L1 (m)	Estimate	1266.50	371.89	0.30	0.33	0.19	0.18
	Estimated Error	310.60	384.38	0.21	0.21	0.16	0.17
	Lower 95% CI	573.30	-383.15	0.01	0.02	0.01	0.01
	Upper 95% CI	1791.30	1143.04	0.74	0.78	0.60	0.65
CMJ (cm)	Estimate	38.70	7.83	0.21	0.24	0.34	0.21
	Estimated Error	2.65	3.38	0.16	0.16	0.19	0.16
	Lower 95% CI	32.42	1.65	0.01	0.01	0.03	0.01
	Upper 95% CI	43.02	15.03	0.62	0.61	0.74	0.57
FMS (score)	Estimate	16.60	0.32	0.31	0.24	0.21	0.24
	Estimated Error	0.86	1.15	0.22	0.19	0.18	0.18
	Lower 95% CI	14.54	-1.76	0.01	0.01	0.01	0.01
	Upper 95% CI	18.10	2.82	0.77	0.70	0.67	0.67
Maturity offset (years)	Estimate	-2.05	-0.11	0.29	0.25	0.22	0.23
	Estimated Error	0.49	0.63	0.21	0.19	0.19	0.19
	Lower 95% CI	-2.92	-1.46	0.01	0.01	0.01	0.01
	Upper 95% CI	-0.95	1.03	0.76	0.71	0.69	0.69
5m sprint (s)	Estimate		-0.07	1.08	0.43	0.28	0.29
	Estimated Error		0.04	0.02	0.22	0.19	0.20
	Lower 95% CI		-0.15	1.04	0.03	0.01	0.01
	Upper 95% CI		0.00	1.13	0.86	0.74	0.73
20m sprint (s)	Estimate	3.44	-0.24	0.22	0.26	0.30	0.22
	Estimated Error	0.09	0.12	0.16	0.17	0.18	0.15
	Lower 95% CI	3.29	-0.49	0.01	0.02	0.02	0.01
	Upper 95% CI	3.64	-0.02	0.61	0.65	0.69	0.57

2 and 3 in the lead coach's ratings for speed, and the highest difference, between ratings 3 and 4 in the lead coach's ratings for endurance and the assistant coach's rating of speed between ratings of 1 and 2, both at 43%.

5.4 Discussion

This study aimed to examine relationships between coaches' ratings of players on a range of generic physical abilities relative to successful soccer performance, and a corresponding physical fitness test that measured each ability. Additionally, this study aimed to examine inter-rater agreement between two coaches (lead vs. assistant) when examining physical abilities of youth soccer players. Lead and assistant coaches displayed moderate-substantial agreement in their ratings of perceived physical qualities of players, however, relationships between objective (fitness test performance) and subjective (coach ratings) were skewed in nature and displayed varied levels of variance across tests.

Levels of agreement between the lead and assistant coaches were lowest (moderate) for 'endurance', and highest (substantial) for 'power' (**Table 5.2**). These findings suggest that, whilst moderate agreement between coaches was observed, coaches possess somewhat different perceptions of what constitutes poor-good endurance capacities within competitive youth soccer performance. It is possible that this discrepancy is due to the intermittent nature of soccer, and the multitude of exercise modalities and energy systems utilised within competition (Buchheit *et al.*, 2010; Seward *et al.*, 2016). It has been suggested that "endurance" comprises various facets including both aerobic and anaerobic capacities (Bangsbo *et al.*, 2006; Stølen *et al.*, 2005), with multiple procedures being implemented to assess the repeated and intermittent nature of soccer performance (Buchheit, 2008; Hill-Haas *et al.*, 2011; Krstrup *et al.*, 2003, 2006). This ambiguity regarding endurance capacity could therefore distract from a cohesive inter-rating perception and rating of this ability. On the contrary, coaches' perceptions of 'power' displayed substantial agreement within this sample, suggesting that actions displaying what coaches perceive as 'power' are more universally identifiable during soccer play. Moreover, ratings of 'acceleration' and 'speed'

produced substantial agreement between coaches. Explosive movements such as jumping and sprinting have been previously reported to possess collinearity (Comfort *et al.*, 2014), therefore it is possible that whilst coaches may attribute various physical capacities under the domain of 'power', relationships between these capacities minimise interference and distraction during the rating process and thereby improve between-coach agreement.

Whilst levels of agreement between coaches were moderate-substantial across all measures (**Table 5.2**), ratings provided by lead coaches explained more variance in test performance than those awarded by assistant coaches for 5 out of 6 physical characteristics (**Table 5.3**). Lead coaches within this sample possessed more coaching experience and time spent coaching their current team, both previously suggested as factors that may impact on the accuracy of such ratings (Roca, Williams, & Ford, 2012; Sieghartsleitner *et al.*, 2019). These differences, however, were small. Therefore, it is perhaps more likely that more experience and responsibility regarding team decision making and selection/deselection procedures by the lead coach resulted in more accurate and informed ratings being assigned (Musculus & Lobinger, 2018).

Coaches' ratings were particularly accurate when rating the highest performers as they correctly rated the best objectively assessed performers in 5 out of 6 tests (lead coach), and 4 out of 6 tests (assistant coach) (**Table 5.4**). Coach ratings were also reasonably accurate when rating the lowest performers, correctly rating the worst objectively assessed performers for 3 out of 6 tests (lead coach) and 4 out of 6 tests (assistant coach). The skewed nature of data observed between coach rating and fitness test performance supports the method of using coach-based rating/ranking procedures for talent identification processes, as coaches seem to be able to correctly identify individuals at the extremities of a scale

(lowest/highest) (Fenner *et al.*, 2016; Unnithan *et al.*, 2012; Williams & Reilly, 2000). The finding that stepwise increases related to progressively higher ratings for only one performance test per coach however, suggests this method potentially lacks sensitivity to differentiate across the entire rating scale (**Figure 5.2**). Moreover, the non-linear nature of the regression model derived from this data demonstrates the uneven assignment of ratings by both the lead and assistant coach (**Figure 5.3**). As previously discussed, coaches exhibited reasonable accuracy when providing ratings for lowest/highest performers. However, explained variance between ratings scores (1-5) varied, with no consistent trend observed across performance qualities for both lead (**Table 5.5**) and assistant (**Table 5.6**) coaches. This highlights the subjective and potentially biased nature associated with coach rating systems and a lack of ability to differentiate between performers of similar abilities (Meylan *et al.*, 2010). Similarly, this finding may also raise question on how discriminatory subjective measurement scales need to be, and, whether valuable information could be elicited from a more simplistic scale (eg. top vs. bottom performers). Alternatively, the finding raises questions regarding generic physical fitness tests to assess characteristics appropriate to successful soccer performance.

An interesting premise is how developments in chronological age and maturation affect relationships between objective and subjective judgements. Previous research suggests that subjective ratings are dynamic and change over time (Hendry *et al.*, 2018). Moreover, there is a tendency for coaches and practitioners to subconsciously or consciously favour physical and anthropometric characteristics rather than technical capacities of young players (Carling *et al.*, 2009; Unnithan *et al.*, 2012). Therefore, the vast physical and physiological progressions experienced across adolescence may influence subjective ratings throughout these developments. The sample in the current study contained players recruited from a

professional youth soccer academy. Following findings that coaches displayed reasonable accuracy when rating highest/lowest performers, it would be of interest to replicate this study with a sample recruited from multiple playing standards, comparable to the approach of **Chapter 3** of this thesis. Therefore, in future, researchers should consider comparing relationships between coach ratings and in-game variables, from GPS units or similar, collected simultaneously from a sample containing a diverse range of abilities.

5.5 Conclusion

Whilst inter-rater agreement between the lead and assistant coach was moderate-substantial for the qualities rated within this study, relationships between coach subjective rating and a corresponding fitness test were accurate only for highest/lowest performers. The translation between objective and subjective assessment methods may be effective when attempting to differentiate between distinct population groups, however this method may lack sensitivity when evaluating homogeneous samples.

X – SYNTHESIS (CHAPTER 5 – CHAPTER 6)

In the final chapter of this PhD thesis (**Chapter 6**), performance on physical fitness tests relative to successful youth-senior transition will be assessed. Whilst **Chapter 3** explored the discriminative ability of physical fitness tests to differentiate between varied performance standards, this chapter adopted a cross-sectional approach. As discussed during **Section 2.1** and **Section 2.4**, more representative information on the TI process may be derived from longitudinal studies, where the outcome is successful youth-senior transition.

Findings from this final experimental chapter will better inform on how physical qualities of players influence subsequent progression to a professional contract, and inform how practitioners may interpret these data throughout the training and development process relevant to TI.

CHAPTER 6

IDENTIFYING PHYSICAL VARIABLES RELATED TO YOUTH-SENIOR PROGRESSION: A 12 YEAR REVIEW OF FITNESS TEST DATA IN ACADEMY YOUTH SOCCER

Abstract

Given the limited capacity of professional soccer academies, strategies to assess, monitor, and evaluate players as they progress through adolescence towards professional senior soccer are commonly adopted by coaches and practitioners. Longitudinal study designs examining performance throughout adolescence are considerably less prevalent than cross-sectional study designs within the literature. This study aimed to investigate differences in age of recruitment alongside longitudinal performance differences on field-based fitness tests of successful vs. unsuccessful graduates across the entire age spectrum recruited by a professional soccer academy. Five-hundred-and-thirty-seven Scottish youth soccer players volunteered to participate in this study. Age of recruitment, biannual fitness test performance, and subsequent success in attaining a senior professional contract at the club were recorded. Of the 537 players, only 53 (10%) players were successful in obtaining a professional contract, with 68% of successful players being recruited at 12-years of age or older. Bayesian regression models report a consistent interaction between age and group for regression models fitted to performance data from this study, across all performance measures. Individuals recruited at an earlier age did not display higher probability of success in attaining a professional contract. Moreover, “successful” academy graduates were only observed to physically outperform their “unsuccessful” counterparts from ~13-14 years of age onward, with either no differences in performance, or, performance on physical fitness tests favouring “unsuccessful” players prior to this age. These findings further support the notion that high achievers during childhood and early adolescence may not translate into successful senior professionals and raises questions towards predictive and early specialisation models of TI.

6.1 Introduction

The central goal of soccer academies around the world is to develop talented youth players into valuable and high performing senior professionals (Unnithan *et al.*, 2012; Williams & Reilly, 2000). Given the limited capacity of professional soccer academies, strategies to assess, monitor, and evaluate players as they progress through adolescence are commonly adopted by coaches and practitioners (Pastor-Vicedo *et al.*, 2017; Vaeyens *et al.*, 2008). Subsequently, metrics and data gathered from these strategies are used to support and influence decision making during selection/deselection and progression throughout a soccer academy campaign (Huijgen *et al.*, 2014).

As extensively evaluated in **Chapters 3–5**, a prevalent monitoring and testing strategy, used within soccer, for both youth and senior populations is physical fitness testing. Discussed during **Section 2.3** of this thesis, and implemented during **Chapter 3**, abilities of cardiovascular fitness, strength/power, linear and multi-directional sprinting, and anthropometric/morphologic characteristics are commonly evaluated as part of many youth and senior soccer programs (Paul & Nassis, 2015a; Rampinini *et al.*, 2007). Whilst the complex and multi-faceted nature of competitive soccer performance limits ability to base talent assessments solely upon physical fitness testing (Unnithan *et al.*, 2012; Vaeyens *et al.*, 2006; Williams & Reilly, 2000), fitness tests are commonly used within youth soccer academy operations and practices in conjunction with subjective game-based and technical evaluations (**Section 2.1, Chapter 5**). However, given the potential lack of agreement between subjective and objective measures of physical ability, demonstrated by the findings of **Chapter 5** of this thesis, an understanding of how physical abilities relate to youth-senior transition on a longitudinal basis may provide valuable information to further inform TI and TD practices.

Physical fitness abilities corresponding to TI and selection/deselection in youth soccer have been heavily investigated using cross-sectional approaches (Hulse *et al.*, 2013; Rebelo *et al.*, 2013; Reilly *et al.*, 2000; Dodd & Newans, 2018; Murr, Raabe, *et al.*, 2018). However, longitudinal study designs examining comprehensive batteries of physical fitness characteristics throughout adolescence, relative to successful transition from youth-senior soccer, are considerably less prevalent (Emmonds *et al.*, 2016; Gonaus & Müller, 2012; le Gall *et al.*, 2010). Emmonds *et al.* (2016) evaluated English youth soccer players successful or unsuccessful in receiving a professional contract from a professional soccer academy at 18 years of age. The authors report improved 10m/20m sprint and YYIRT L1 performance by successful compared to unsuccessful players at U16 and U18 age groups. Similarly, both Gonaus & Müller (2012) and le Gall *et al.* (2010) report differences in a range of physical qualities at various stages of development between successful vs. unsuccessful graduates of professional soccer academies, reporting that successful graduates perform generally better across a range of physical fitness tests. Seemingly, comparable to cross-sectional data on youth soccer players, these longitudinal studies display findings centred upon senior academy players (U14-U17) (Emmonds *et al.*, 2016; Gonaus & Müller, 2012; le Gall *et al.*, 2010). Therefore, previous findings provide limited knowledge on the differences in fitness test performance apparent throughout earlier years of academy soccer players (<U14). Given that academies commonly recruit players as young as U9 (Hulse *et al.*, 2013), and the proclaimed importance around both early recruitment and increased time spent within an academy associated with successful youth-senior transition within soccer (Larkin & O'Connor, 2017; Reilly *et al.*, 2000; Wrigley *et al.*, 2014), information across the entire age range recruited by a professional soccer academy would provide useful information for academics and practitioners.

Accordingly, the aim of this study was to: i) investigate the differences in age of recruitment and relative time spent within an academy infrastructure with regards to successful vs. unsuccessful academy graduation, and; ii) examine performance differences on field-based fitness tests of successful vs. unsuccessful graduates across the entire age spectrum recruited by a professional soccer academy. It is hypothesised that successful academy graduates will outperform unsuccessful academy graduates across a range of physical fitness tests, particularly evident within older age groups as observed previously, and, will be recruited at a relatively younger age, spending relatively longer periods of time developing within the academy infrastructure.

6.2 Methods

Participants:

Adopting a longitudinal database study design (February 2006 until December 2017), five-hundred-and-thirty-seven professional club Scottish youth soccer players (mean \pm SD [range]: age 12.4 ± 1.9 [8.0-17.0] years; stature 158.4 ± 14.0 [125.0-193.4] cm; mass 48.2 ± 13.0 [22.4-89.4] kg) with years of birth ranging from 1990 to 2007, volunteered to participate in this study. At the time of data collection, participants were currently signed to a professional soccer academy playing within the Scottish Football Association (SFA) top tier of youth soccer. Players were categorised in terms of subsequent career progression: “successful” (n = 53) vs. “unsuccessful” (n = 484) with regards to being offered a professional contract following academy graduation at the current club (Scottish Premiership/Championship). Participant and parental/guardian consent was gained alongside providing comprehensive written and oral explanations about the study. The study received institutional ethical approval.

Procedures:

Participants completed a generic physical fitness testing battery twice per year at the beginning of the summer (July/August) and winter (December/January) training periods. At each time point, anthropometric (mass, standing stature) and performance (5/10/20m linear sprint, countermovement jump (CMJ), and Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IRT L1)) data were collected from each participant. Descriptive data (names, D.O.B) for participants was gathered from the academy database and provided by the academy director. To account for circadian variability (Drust *et al.*, 2005), testing sessions were completed at the same time of day and during participants’ regular scheduled training hours. Testing sessions

were completed a minimum of 48hours following a competitive game, and in absence of strenuous exercise within 24hours prior. Testing sessions were conducted indoors on a non-slip surface with a temperature of ~22°C. All players received the same standardised warm-up consisting of light aerobic activity, dynamic stretching, progressive sprinting, and sub-maximal jump variations. Tests were completed in a standardised order and arranged from least-most physically demanding by the research team to minimise cumulative fatigue. For the linear sprint and CMJ tests, participants completed 3 attempts with the best attempt for each distance being selected for analysis.

Anthropometrics

Standing stature was assessed using a free-standing stadiometer (Seca, Birmingham, UK) and reported to the nearest 0.1cm. Body mass was assessed using digital floor scales (Seca, Birmingham, UK) and reported to the nearest 0.1kg.

5/10/20m sprint

Linear speed and acceleration were assessed over a distance of 5/10/20m as per previously reported match-based observations of youth soccer players (Buchheit *et al.*, 2010; Mendez-Villanueva *et al.*, 2011). Sprint data were collected via the Brower TC Timing System (Brower Timing Systems, Draper, UT), and reported to the nearest 0.01s. Timing gates were adjusted to an appropriate height as per the mean stature of the sample group, and start positions were standardised at 0.7m behind the start gate (Haugen & Buchheit, 2016).

Countermovement jump (CMJ)

CMJ data were collected using the Just Jump mat (Probiotics, Huntsville, AL). Attempts were conducted adopting the arms akimbo position and utilising a self-selected countermovement

depth. Attempts were disqualified if participants abandoned the arms akimbo position or actively flexed at the knee or hip during flight. For all CMJ attempts, participants performed a ballistic descent-ascent to their self-selected depth. Data were reported to the nearest 0.1cm via the Just Jump handheld unit.

Yo-Yo Intermittent Recovery Test Level 1 (YYIRT L1)

The YYIRT L1 was conducted according to methods outlined by (Krustrup *et al.*, 2003). Participants were instructed to perform the test to exhaustion and were withdrawn from the test following two consecutive failures to reach the finishing line in time. The distance covered during the test was recorded in metres and represents the finishing level of the test. Participants were familiarised to the test by at least one pre-test.

Statistical Analysis:

Descriptive statistics associated with the age participants entered the academy and success in obtaining a professional contract at the present club, or being released, are reported as percentages (%). Descriptive statistics of physical test performance and anthropometrics for successful vs. unsuccessful players are presented as means \pm standard deviations (SD). The log odds of a player obtaining a professional contract given the year they joined the academy was modelled using a Bayesian logistic regression model with a logit link function. Success in obtaining a professional contract or not (1 = successful, 0 = not successful) was modelled as the dependent variable and age on entering the academy as the predictor. Probabilities of success were calculated for all ages with odds ratios calculated for comparisons between ages.

To determine if physical performance predicted whether a player was successful vs. unsuccessful in being signed to a professional contract by the academy, a series of Bayesian regression models allowing for unequal variances between groups were fitted. Differences were modelled for 5/10/20m sprint, CMJ, and YYIRT L1, along with player stature and mass. Given measurements were made at different ages, age was included as a moderator in all models and centred using 10-years of age as a reference point – the youngest age both successful and unsuccessful players were recruited to the academy. A Bayesian version of R^2 was calculated along with direct probabilities of a difference between group estimates and slopes calculated from each model. Probability values presented can be interpreted directly as a percentage chance of a difference in a direction. For example, $\text{prob}=0.9$ means a 90% chance of the difference greater than zero and a 10% chance the difference is less than zero. Equally, $\text{prob}=0.5$ means a 50% chance of the difference being above zero, but also a 50% chance of it being less than zero, therefore highly uncertain. To illustrate the differences between successful and unsuccessful players at different ages, the models were used predict each of the measured variables at each age. Estimates from the models are presented along with 95% credible intervals (95%CI). All analyses were conducted using R (R Core Team, 2018).

6.3 Results

Age and success

Descriptive statistics suggest more players were recruited at 10-years of age than at any other age, with 148 players starting the academy at this age. Only four 8-year olds were recruited to the academy (the lowest number of recruits for any age group), followed by 16-year olds with ten recruits (**Table 6.1**).

Table 6.1 Percentages of successful vs. unsuccessful players given their starting age.

Age starting academy (years)	n	% Successful	% Unsuccessful	% Players recruited (total)
8	4	0.00	100.00	0.75
9	62	0.00	100.00	11.55
10	148	7.43	92.57	27.56
11	82	7.32	92.68	15.27
12	62	16.13	83.87	11.55
13	83	13.25	86.75	15.46
14	45	13.33	86.67	8.38
15	41	17.07	82.93	7.64
16	10	20.00	80.00	1.86
			Total	100.00

Of the 537 players, only 53 (10%) players recruited to the academy were successful in obtaining a professional contract. Of the successful players, 68% were recruited to the academy at 12-years of age or older. While those recruited at 16 years of age achieved the greatest percentage of success, only two players from this age group obtained a contract. Age groups with the highest number of successful recruits were 11- and 13-year olds with eleven players successfully getting signed to a professional contract from both of these age groups.

The Bayesian logistic regression, accounting for unequal variance, predicting how likely players are to successfully obtain a contract given the age they start an academy, suggests that players starting at 16 years are most likely be successful in gaining a contract (0.17) and those starting at 8 and 9 the least likely (0.00). However, there is high uncertainty around these predictions (**Figure 6.1**).

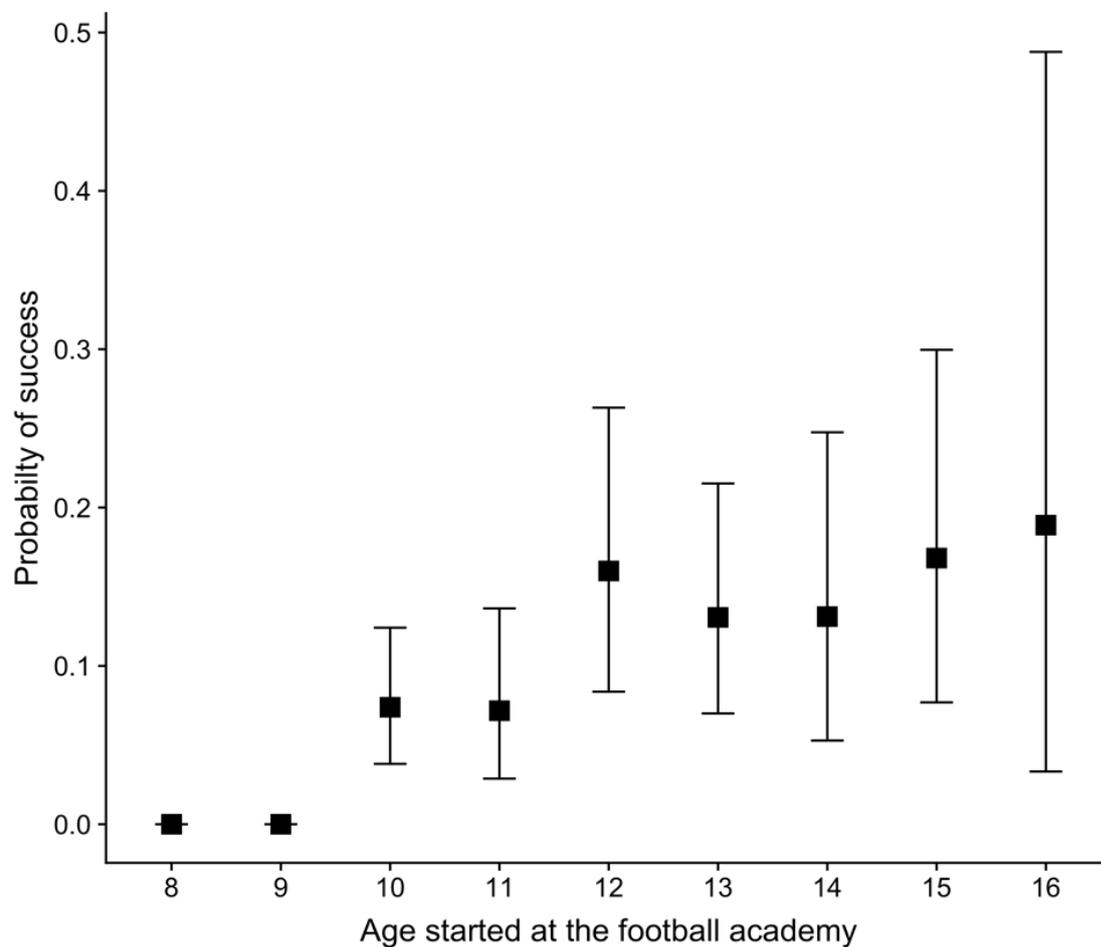


Figure 6.1 Bayesian logistic regression model of probability of obtaining a professional contract given a player's starting age in the academy. Data are displayed as estimates \pm 95%CI.

Indicators of success

5, 10, and 20m sprints:

Minimal differences were observed between successful vs. unsuccessful players across distances of 5, 10 or 20m. Until the age of 14 years old, successful players were observed to be slower than their unsuccessful counterparts (**Table 6.2**). The results of the Bayesian regression models fitted to determine performance differences between successful and unsuccessful players suggest a meaningful interaction between age and group in explaining sprint times across all sprint distances measured (**Table 6.3**).

The regression model for 5m sprint ($R^2 = 0.25$), shows that successful players reduced their sprint time by 0.03 seconds per year (prob>0.99), whereas for unsuccessful players, sprint times reduce by 0.02 seconds per year (prob>0.99). Similar age by group interaction effects were found for 10m sprint ($R^2 = 0.38$), showing that successful players reduced their sprint times reduced by 0.05 seconds per year (prob>0.99), and unsuccessful players by 0.04 seconds per year (prob=0.99). Over 20 metres ($R^2 = 0.59$), successful players reduced their sprint times by 0.11 seconds per year (prob>0.99), and unsuccessful players by 0.10 seconds per year (prob>0.99). Predictions from the regression models suggest that unsuccessful players are initially the fastest over 5, 10 and 20 metres. Nonetheless, from 15-years onwards, successful players perform better at 5 metre sprints, at 16-years onwards for 10 metre sprints, and from 14-years onwards for 20 metre sprints (**Figure 6.2**).

Table 6.2 Descriptive statistics for 5/10/20m sprint, CMJ, YYIRT L1, stature, and mass for successful vs. unsuccessful players aged 10-17.

		Age at test							
		10-years	11-years	12-years	13-years	14-years	15-years	16-years	17-years
5m sprint (s)	Successful	1.16 ± 0.10	1.15 ± 0.09	1.11 ± 0.07	1.06 ± 0.06	1.03 ± 0.07	1.02 ± 0.07	0.99 ± 0.07	0.96 ± 0.07
	Unsuccessful	1.12 ± 0.07	1.11 ± 0.07	1.08 ± 0.06	1.05 ± 0.07	1.04 ± 0.07	1.03 ± 0.06	1.02 ± 0.07	1.01 ± 0.07
10m sprint (s)	Successful	2.03 ± 0.14	2.01 ± 0.12	1.94 ± 0.10	1.85 ± 0.08	1.82 ± 0.12	1.78 ± 0.12	1.76 ± 0.10	1.70 ± 0.08
	Unsuccessful	1.99 ± 0.11	1.95 ± 0.09	1.90 ± 0.09	1.85 ± 0.11	1.82 ± 0.11	1.79 ± 0.10	1.76 ± 0.10	1.74 ± 0.08
20m sprint (s)	Successful	3.63 ± 0.22	3.56 ± 0.20	3.43 ± 0.15	3.27 ± 0.12	3.13 ± 0.17	3.08 ± 0.15	3.02 ± 0.12	3.03 ± 0.10
	Unsuccessful	3.55 ± 0.16	3.49 ± 0.16	3.39 ± 0.14	3.27 ± 0.16	3.17 ± 0.15	3.08 ± 0.14	3.03 ± 0.12	3.01 ± 0.11
CMJ (cm)	Successful	22.0 ± 3.9	25.0 ± 4.1	27.8 ± 4.1	31.3 ± 4.3	33.6 ± 5.9	35.7 ± 3.3	37.8 ± 3.8	35.9 ± 3.6
	Unsuccessful	23.3 ± 3.9	25.1 ± 4.3	27.0 ± 4.5	30.0 ± 4.8	32.9 ± 4.8	36.0 ± 4.8	37.2 ± 4.4	35.5 ± 4.1
YYIRT L1 (m)	Successful	769 ± 480	993 ± 513	1425 ± 343	1728 ± 474	2139 ± 427	2238 ± 521	2349 ± 383	2320 ± 788
	Unsuccessful	1020 ± 381	1206 ± 410	1486 ± 444	1677 ± 495	1926 ± 541	2044 ± 577	2229 ± 518	1830 ± 388
Stature (cm)	Successful	143.9 ± 5.2	148.2 ± 5.6	154.0 ± 6.4	161.6 ± 7.4	169.6 ± 6.6	174.1 ± 5.8	177.1 ± 5.5	180.0 ± 4.6
	Unsuccessful	143.1 ± 6.2	147.8 ± 6.7	154.6 ± 7.4	163.0 ± 8.1	170.1 ± 7.4	175.2 ± 6.6	176.0 ± 6.2	177.7 ± 5.3
Mass (kg)	Successful	37.2 ± 6.9	39.1 ± 6.3	44.6 ± 6.5	49.8 ± 6.6	57.6 ± 7.5	64.1 ± 7.4	67.6 ± 8.3	70.2 ± 6.2
	Unsuccessful	35.3 ± 5.2	38.6 ± 8.0	43.6 ± 8.9	50.5 ± 7.8	58.2 ± 8.4	64.3 ± 7.4	67.3 ± 7.1	72.0 ± 6.0

Data are presented as mean ± SD

Table 6.3 Predictions and lower/upper 95%CI from the Bayesian regression model for differences in 5, 10, and 20 metre sprint times for successful vs. unsuccessful players.

		Age at test								
		10-years	11-years	12-years	13-years	14-years	15-years	16-years	17-years	
5m sprint (s)	Successful	Estimate	1.16	1.13	1.10	1.07	1.04	1.01	0.98	0.95
		Lower 95 % CI	1.02	0.99	0.96	0.93	0.90	0.87	0.84	0.81
		Upper 95% CI	1.30	1.27	1.25	1.21	1.18	1.15	1.12	1.09
	Unsuccessful	Estimate	1.12	1.10	1.08	1.06	1.04	1.02	1.00	0.98
		Lower 95 % CI	0.99	0.97	0.94	0.93	0.91	0.89	0.99	0.85
		Upper 95% CI	1.26	1.24	1.22	1.20	1.18	1.15	1.14	1.11
10m sprint (s)	Successful	Estimate	2.03	1.97	1.93	1.88	1.83	1.78	1.73	1.68
		Lower 95 % CI	1.81	1.75	1.72	1.67	1.61	1.56	1.51	1.46
		Upper 95% CI	2.24	2.19	2.15	2.10	2.05	2.00	1.95	1.91
	Unsuccessful	Estimate	1.99	1.95	1.91	1.86	1.82	1.78	1.74	1.70
		Lower 95 % CI	1.80	1.75	1.71	1.66	1.63	1.59	1.55	1.50
		Upper 95% CI	2.19	2.14	2.11	2.06	2.01	1.98	1.94	1.91
20m sprint (s)	Successful	Estimate	3.61	3.51	3.39	3.29	3.18	3.08	2.96	2.86
		Lower 95 % CI	3.28	3.18	3.07	2.97	2.87	2.78	2.68	2.58
		Upper 95% CI	3.95	3.84	3.72	3.60	3.48	3.36	3.25	3.14
	Unsuccessful	Estimate	3.56	3.47	3.37	3.28	3.19	3.09	3.00	2.91
		Lower 95 % CI	3.25	3.16	3.08	3.00	2.91	2.82	2.74	2.66
		Upper 95% CI	3.88	3.78	3.68	3.57	3.48	3.37	3.27	3.17

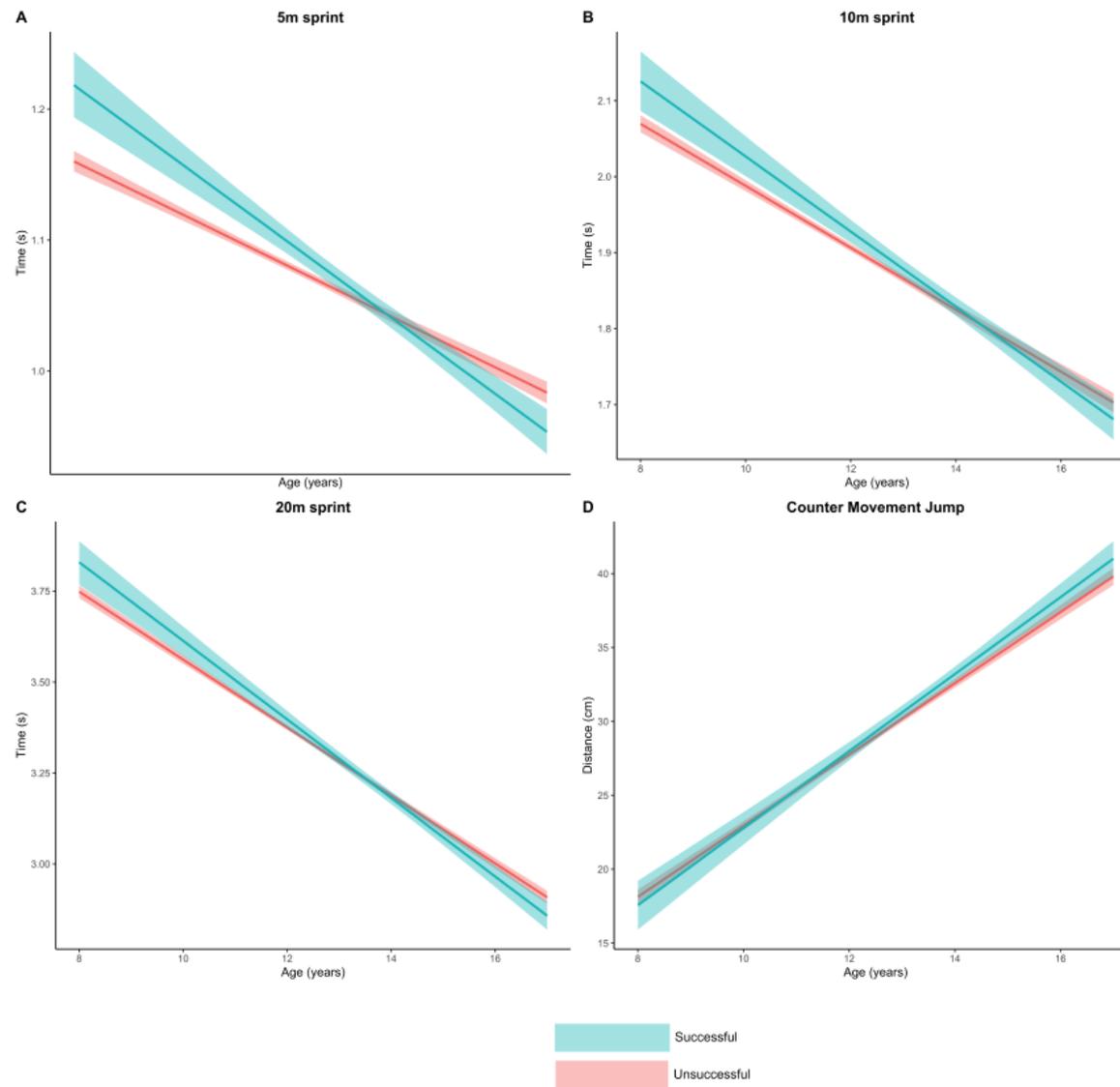


Figure 6.2 Interaction plots between age and success for: **A)** 5m sprint; **B)** 10m sprint; **C)** 20m sprint; **D)** CMJ; **E)** YYIRT L1; **F)** Stature, and; **G)** Mass.

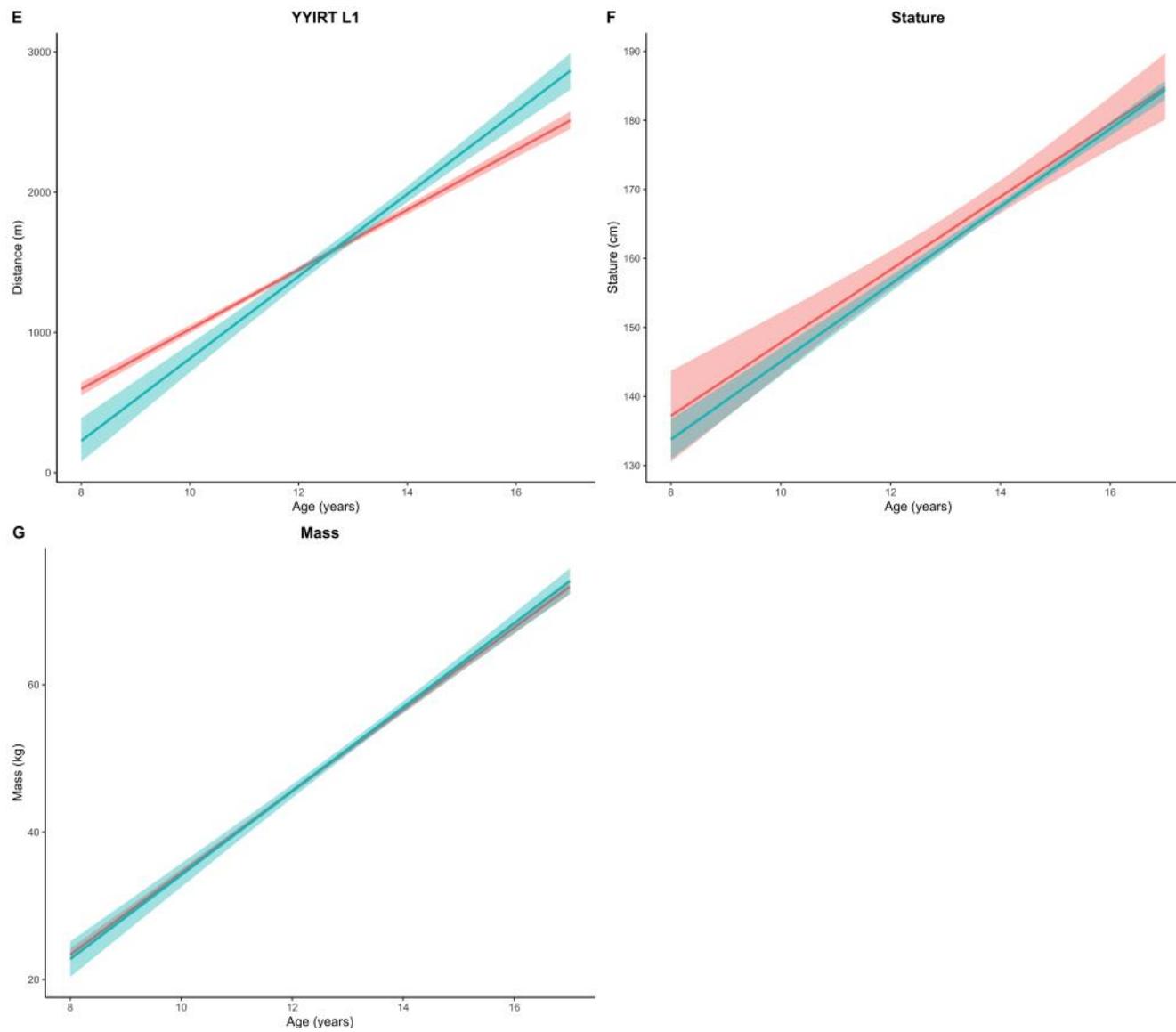


Figure 6.2 Interaction plots between age and success for: **A)** 5m sprint; **B)** 10m sprint; **C)** 20m sprint; **D)** CMJ; **E)** YYIRT L1; **F)** Stature, and; **G)** Mass.

Countermovement jump (CMJ) and Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT L1):

Descriptive statistics for CMJ suggest minimal differences between successful vs. unsuccessful players (**Table 6.2**). Results of the Bayesian regression model for differences in CMJ height ($R^2 = 0.53$) between successful vs. unsuccessful players suggest a meaningful age by group interaction. The model suggests that the successful group increased jump height by 2.6 cm per year (prob>0.99) compared to the unsuccessful group who increased jump height by 2.4 cm per year (prob=0.90) (**Table 6.4**). Predictions from the model suggest from age 11-years onwards, players in the successful group, on average, outperform those in the unsuccessful group on the CMJ (**Figure 6.2**). Descriptive statistics suggest that, from age 13-years onwards, successful players covered more distance on the YYIRT L1 (**Table 6.2**). Results of the Bayesian regression model for differences in YYIRT L1 distance ($R^2 = 0.47$) between successful vs. unsuccessful players again suggests a meaningful age by group interaction. The distance covered by successful players increased by 293 m per year (prob>0.99) compared to the unsuccessful group who increased distance by 213 m (prob>0.99) (**Table 6.4**). Predictions from the model suggest that while initially players in the unsuccessful group, on average, covered more distance during the YYIRT L1 test than those in the successful group, from age 13-years onward, the successful group outperformed the unsuccessful group (**Figure 6.2**).

Stature and Mass:

Descriptive statistics suggest successful players tended, on average, to be taller from 16-years onward. However, prior to that, there was little difference in height between successful and unsuccessful players, or actually the unsuccessful group were taller (**Table 6.2**). Descriptive statistics for body mass for successful vs. unsuccessful players suggest minimal differences. Nonetheless, between the ages 10 to 12 years, successful players tended to be heavier than

unsuccessful players (**Table 6.2**). Results of the Bayesian regression model for differences in stature ($R^2 = 0.75$) suggest that the height of successful players increased by 6.1 cm each year (prob>0.99), whereas unsuccessful players height increased by 6.3 cm (prob=0.82) (**Table 6.5**). The model predicts minimal differences in height between successful and unsuccessful players at 17-years of age (**Figure 6.2**). Differences in body mass ($R^2 = 0.70$) between successful and unsuccessful players across ages are equally uncertain (**Table 6.5**). Body mass of successful players increased by 5.7 kg each year (prob>0.99), whereas unsuccessful players weight increased by 5.5 kg (prob=0.77). The model predicts minimal differences in mass between successful and unsuccessful players at 17-years of age (**Figure 6.2**).

Table 6.4 Predictions and lower/upper 95%CI from the Bayesian regression model for differences in YYIRT L1 and CMJ performance for successful vs. unsuccessful players.

		Age at test								
		10-years	11-years	12-years	13-years	14-years	15-years	16-years	17-years	
YYIRT L1 (m)	Estimate	809	1104	1402	1698	1987	2277	2561	2864	
	Successful	Lower 95 % CI	104	349	571	812	1050	1239	1402	1665
		Upper 95% CI	1514	1858	2203	2611	2936	3306	3734	4084
	Unsuccessful	Estimate	1018	1235	1446	1665	1873	2095	2309	2514
		Lower 95 % CI	263	427	551	739	867	982	1117	1250
		Upper 95% CI	1756	2024	2321	2590	2862	3176	3538	3781
CMJ (cm)	Estimate	22.5	25.5	28.0	30.7	33.2	35.8	38.5	40.9	
	Successful	Lower 95 % CI	14.4	17.2	19.4	21.9	23.9	26.4	28.7	30.9
		Upper 95% CI	30.6	33.7	36.6	39.4	42.1	44.9	47.9	50.9
	Unsuccessful	Estimate	23.0	25.4	27.8	30.2	32.5	35.1	37.4	39.9
		Lower 95 % CI	14.9	16.9	19.1	21.3	23.2	25.0	27.7	29.5
		Upper 95% CI	31.2	33.5	36.4	39.0	41.9	44.6	47.5	50.2

Table 6.5 Predictions and lower/upper 95%CI from the Bayesian regression model for differences in stature and mass for successful vs. unsuccessful players.

		Age at test								
		10-years	11-years	12-years	13-years	14-years	15-years	16-years	17-years	
Stature (cm)	Successful	Estimate	143.2	149.2	155.4	161.4	167.8	173.6	179.8	185.8
		Lower 95 % CI	131.8	137.7	143.2	149.1	155.0	160.0	165.6	171.1
		Upper 95% CI	155.2	160.7	167.5	173.8	181.0	187.0	193.8	200.6
	Unsuccessful	Estimate	142.8	149.1	155.3	161.9	168.0	174.4	180.7	187.1
		Lower 95 % CI	129.9	135.8	141.4	147.4	153.2	158.4	164.5	170.4
		Upper 95% CI	155.6	162.4	169.4	175.9	182.8	190.0	197.0	203.0
Mass (kg)	Successful	Estimate	34.3	39.8	45.8	51.3	57.0	62.6	68.3	73.7
		Lower 95 % CI	22.8	28.3	33.4	37.7	42.3	47.0	52.5	54.9
		Upper 95% CI	45.4	51.8	58.7	64.6	72.0	78.0	84.9	92.6
	Unsuccessful	Estimate	34.4	39.9	45.5	50.9	56.2	61.9	67.4	72.7
		Lower 95 % CI	23.5	28.2	32.5	37.3	41.2	45.4	49.2	53.7
		Upper 95% CI	45.5	51.7	58.6	64.7	71.3	78.0	84.6	92.2

6.4 Discussion

This study aimed to investigate differences in age of recruitment and relative time spent within an academy infrastructure with regards to successful vs. unsuccessful attainment of a professional contract upon graduation at a professional soccer academy. This study also aimed to examine performance differences on physical fitness tests of successful vs. unsuccessful graduates across the entire age spectrum recruited by the academy. Individuals recruited at an earlier age did not display higher probability of success in attaining a professional contract. Moreover, “successful” academy graduates were only observed to physically outperform their “unsuccessful” counterparts from ~13-14 years of age onward, with either no differences in performance, or, performance on physical fitness tests favouring “unsuccessful” players prior to this age.

Despite suggestion that early recruitment into a professional soccer academy is important when considering absolute outcomes of long-term success in soccer (le Gall *et al.*, 2010; Meylan *et al.*, 2010), when considering physical performance characteristics, these findings suggest otherwise. Findings of the present study are in agreement with Hertzog *et al.* (2018) and Güllich (2014), who highlight uncertainty around early recruitment relative to successful transition to senior soccer. Whilst small sample numbers present at both ends of the age spectrum may have influenced results regarding successful vs. unsuccessful player outcomes (**Table 6.1, Figure 6.1**), these findings are supported by the fact that 68% of successful players, within this sample, were recruited at age 12-years onwards. Resultant of the vast physical/biological changes experienced throughout childhood and adolescence (Malina *et al.*, 2017), alongside non-linear developmental changes in skill and ability (Malina *et al.*, 2015; Meylan *et al.*, 2010; Vaeyens *et al.*, 2008), this finding supports the notion that a more reflective and representative view of player talent and ability may not be possible until the

latter stages of development (Ford & Williams, 2012; Phillips *et al.*, 2010; Vaeyens *et al.*, 2008). This being said, it is widely publicised that expert performance is closely related to the amount of domain-specific deliberate practice accumulated across their careers (Ford, Ward, Hodges, & Williams, 2009). Deliberate practice has been characterised as structured activity with the primary goal of improving an important aspect of current performance. Therefore, with reference to TI and the present study, it is interesting to discover that those who were successful in obtaining a professional contract were those who spent less time within the academy. With regards to TD, however, researchers have advocated engagement in what has been termed “deliberate play” across a wide range of physical activities during childhood, with regards to long-term athletic success (Ford & Williams, 2012). Whilst findings from the present study are limited to one academy only (meaning players may have been involved in other systematic training programmes prior to joining the academy in question), the finding that successful players were, by majority, recruited at age 12 years onward, supports the deliberate play theory.

The influence of adolescence and maturation on developing physical performance characteristics of youth soccer players has been discussed throughout this thesis (**Section 2.2.2.3, Section 2.3, and Chapter’s 3-5**). A consistent interaction between age and group was observed for regression models fitted to performance data from this study, across all measures. Whilst there were no differences, or even that “successful” players perform worse on physical performance measures than “unsuccessful” players during earlier stages of development, this data suggests that “successful” players develop physical characteristics at a greater rate than “unsuccessful” players (**Figure 6.2, Table 6.2, Table 6.3, and Table 6.4**). This finding further supports the premise that physical characteristics substantially develop across adolescence, and, that high achievers during childhood and early adolescence may not

translate into successful senior professionals (Güllich, 2014; Hertzog *et al.*, 2018; Ostojic *et al.*, 2014).

Of the measures included within this study, performance on the 5m sprint and YYIRT L1 were the best indicators of success in obtaining a professional contract upon academy graduation (**Table 6.3**, and **Table 6.4**). This was due to performance differences observed at 17-years of age, and, the substantially greater rate of development over time observed for these measures between successful vs. unsuccessful players (**Figure 6.2**). The importance of YYIRT L1 and short-distance sprint ability to subsequent contract status in youth soccer players has previously been suggested. Deprez, Fransen, *et al.* (2015) propose YYIRT L1 performance to discriminate between retained vs. released players from age 11-years onward, and report speed characteristics to influence future professionalism more so than any other characteristic within their comprehensive battery of physical measures. Similarly, Emmonds *et al.* (2016) report differences in both short-distance sprint speed and YYIRT L1 performance relative to subsequent contract status in their group of English academy youth soccer players. However, differences observed within this sample were only present towards latter years of academy soccer (U16-U18). On the contrary, anthropometric measures of stature and mass proved to be the measures least indicative of professional contract status in our study (**Figure 6.2**, **Table 6.5**). Whilst progressed anthropometric and morphologic characteristics have been identified as potential influencers regarding recruitment and selection/deselection as part of TI system (Carling *et al.*, 2009; Gravina *et al.*, 2008; Rebelo *et al.*, 2013), these findings are inconsistent in the literature, with several authors observing no differences in stature, mass, or body composition across varied performance levels or between “identified” vs. “unidentified” players (Deprez, Buchheit, *et al.*, 2015; le Gall *et al.*, 2010; Vaeyens *et al.*, 2006).

Consequently, the influence of anthropometric characteristics, relative to recruitment, may be questioned.

Although no measure of maturity status, or birth-quartile analysis was conducted as part of this study, the observation that the “unsuccessful” group were, for most measures, higher performers during earlier years of academy football, supports RAE and maturity bias theories. It has been widely reported that youth soccer academy TI and selection/deselection processes favour both early maturing individuals (Meylan *et al.*, 2010; Unnithan *et al.*, 2012; Vaeyens *et al.*, 2008), and chronologically older players (Helsen *et al.*, 2012, 2005; Mujika, Vaeyens, *et al.*, 2009; Vaeyens *et al.*, 2005). Our findings report that the majority of players were recruited to the academy between the ages of 9-11 years (**Table 6.1**), therefore, during recruitment, acute physiological performance may have influenced selection and TI processes. Increased physiological performance during childhood and early adolescence is often accompanied by progressed anthropometric and morphologic characteristics (Carling *et al.*, 2009; Figueiredo *et al.*, 2009; Rebelo *et al.*, 2013). Whilst similar interactions to performance measures were observed for stature and mass within this study, these observations were far less substantial, resulting in highly uncertain predictions from regression models (**Figure 6.2, Table 6.5**).

Translation of findings from the present study may be restricted by potential limitations. Firstly, whilst it is appreciated that this study examined longitudinal performance on a limited battery of generic physical performance tests, it has been reiterated throughout this thesis the prevalence and inclusion of this mode of assessment within the TI process. Undeniably, many unaccounted variables will have affected the success of players within this study, with physical performance being one of many significant contributors to youth-senior progression. Therefore, subsequent youth-senior career progression cannot rely solely on physical

performance characteristics. Future research should therefore consider a more comprehensive array of performance characteristics when seeking to identify more representative indicators of successful youth-senior transition. A second limitation of the present study is that whilst players who were successful in attaining a professional contract at the academy in question were identified, it is unknown whether some players within the unsuccessful player group attained a professional contract at another soccer club. Consequently, players who progressed to a professional contract elsewhere should be deemed “successful”, however, we unfortunately do not possess this data. Future studies should attempt to access governing body databases to identify player success across all represented professional soccer clubs.

6.5 Conclusion

Players recruited earlier into the academy did not have a larger success rate than those recruited later during adolescence. Moreover, successful players, in large, performed worse than their unsuccessful counterparts on physical performance measures during earlier years of academy soccer (U10-U13). However, rates of development observed across adolescence was substantially greater for successful players, contributing towards increased performances upon youth-senior transition (age 17-years). Finally, no differences in either stature or mass were observed between successful and unsuccessful player groups at any age group. These findings further support the notion that high achievers during childhood and early adolescence may not translate into successful senior professionals in Scotland, and raise question towards predictive and early specialisation models of TI.

CHAPTER 7

SUMMARY AND CONCLUSION

Due to recent increases in physical demands of professional soccer training and match play, alongside more densely populated fixture schedules, substantial importance is placed upon developing physical characteristics of soccer players. Subsequently, assessing and monitoring these characteristics is commonplace within daily operations of professional soccer clubs as part of TI and TD processes. Due to the developmental nature of youth soccer, these progressions observed at the professional level have influenced approaches and practices within youth soccer academies during both TI and TD. However, comparative to senior soccer players, the limited experience, diverse physical/biological adaptation and maturation rates, and demands of regularly implemented tests, make interpreting findings much more complex within youth soccer players. Consequently, a thorough appreciation of the value and quality of commonly-used physical fitness tests to provide accurate and representative information on a youth soccer sample is required for appropriate TI and TD processes to occur.

7.1 Aims

The overall aim of this thesis was to better understand how physical fitness testing may be used to contribute towards the TI and TD process of youth soccer players, and how valid physical fitness testing methods may be when being implemented within varied age ranges of youth soccer players. Thereby, developing a better understanding of the value and limitations of physical fitness testing process may assist with the interpretation and weighting

placed upon findings by practitioners, contributing towards a more representative assessment process of youth soccer players.

After a critical evaluation of the current evidence in the literature review, the following specific aims of this doctoral thesis were defined:

1. To examine the cross-sectional and longitudinal ability of a comprehensive physical fitness testing battery to discriminate between ecologically valid and varying abilities of youth soccer players, across a range of ages.
2. To assess the quality of the measures used to assess physical characteristics of youth soccer players across the full age spectrum which they intend to assess.
3. To examine the extent to which physical fitness test performance aligns with coach perception of ability and rating, thus informing decision making relative to TI.
4. To examine the ability of physical fitness testing to provide valuable information relative to soccer performance and success in youth soccer players.

The experimental studies within this thesis were conducted in an attempt to fulfil the presented aims. The purpose of this final chapter is to summarise to what extent these aims have been fulfilled, provide overall practical implications of the studies, and suggest directions for future research in the field as a result of the findings of this thesis.

7.2 Summary of findings

7.2.1 Physical fitness testing as part of the TI process

As discussed throughout this thesis, the premise of correctly and appropriately identifying talented young soccer players is attractive to clubs and coaches. Success, both financially and

competitively, can be influenced by appropriate recruitment and development of youth players, and consequently, is prioritised globally as part of academy operations. Although use of physical fitness testing as part of the TI process has been discussed extensively within the literature (Dodd & Newans, 2018; Gouvêa *et al.*, 2017; Meylan *et al.*, 2010; Paul & Nassis, 2015a; Pearson *et al.*, 2006), knowledge gaps within the literature still exist preventing a fully informed implementation of these methods during TI. Findings from this thesis expand upon knowledge of physical fitness testing as part of the TI process by further clarifying the extent to which physical fitness performance can discriminate between varying abilities, and influence successful youth to senior transition.

In **Chapter 3** of this thesis, a variety of generic and commonly-used fitness tests assessing physical characteristics associated with soccer performance were evaluated across 3 distinct playing standard groups of youth soccer players. Regarding the discriminative ability of these tests to differentiate between performance standards, and potential use as part of TI processes, the main and novel finding of this study was that the selected fitness tests had a 70.2% success rate in correctly classifying “identified” vs. “unidentified” players. However, when assessing fitness test performance differences across different standards of “identified” players (“development” vs. “performance”), only the CMJ test discriminated between the two playing standards in the hypothesised direction (performance > development). In fact, “development” players outperformed “performance” players on both the SBJ and 505COD tests. These results contribute to the growing body of evidence regarding the implementation of physical fitness testing as part of the TI process, however, suggest caution when using this method exclusively to differentiate specifically between homogenous player groups. Whilst age across performance standards was controlled for, during analysis, no measure of maturity status was collected during this study. As “identified” or “selected” players have been

consistently reported to possess a more advanced maturity status comparative to “unidentified” players (Carling *et al.*, 2009; Figueiredo *et al.*, 2009; Towlson *et al.*, 2017; Unnithan *et al.*, 2012), and, considering differences in both stature and mass between “identified” and “unidentified” player groups was observed, this limitation must be acknowledged when interpreting these data. Moreover, absence of intermittent endurance running performance assessment within this study is also acknowledged. Given the prevalence of this characteristic relative to soccer performance (Bangsbo *et al.*, 2006; Castagna *et al.*, 2010; Di Salvo *et al.*, 2009), alongside previous reports regarding its discriminative ability (Goto *et al.*, 2015; Saward *et al.*, 2016; Waldron & Murphy, 2016), it is anticipated that inclusion of assessment of this characteristic would further improve the classification coefficient derived from the analyses of this study.

The historic nature (reliant on scouting systems) (Reilly *et al.*, 2000; Unnithan *et al.*, 2012; Williams & Reilly, 2000), and continued emphasis placed upon coaches’ decisions within TI processes (Grossmann & Lames, 2015; Hendry *et al.*, 2018; Larkin & O’Connor, 2017; Musculus & Lobinger, 2018), requires assessment methods to be representative of abilities comparative to coach’s perceptions. Consequently, when considering TI approaches, desirable and identifiable characteristics, aligned to coach perception, should be assessed.

Chapter 5 of this thesis compared objective performance on a variety of physical performance tests with a corresponding subjective coach rating of perception of ability for that physical characteristic. Whilst findings from this study suggest that coaches were reasonably accurate in their ratings for highest/lowest performers across tests, the finding that stepwise increases related to progressively higher ratings for only one performance test per coach, suggests this method potentially lacks sensitivity to differentiate across homogenous cohorts of soccer players. Considering this finding, future investigation into the degree of discrimination

required to distinguish between abilities. **Chapter 5** of this thesis also suggests that coaches display moderate-to-substantial levels of inter-rater agreement when subjectively rating players' physical characteristics, therefore, subjective feedback regarding physical abilities may remain somewhat consistent throughout the TD process. This suggests that subjective perception of ability is similar between coaches, however, whilst levels of agreement between coaches were moderate-substantial across all measures, ratings provided by lead coaches explained more variance in test performance than those awarded by assistant coaches for 5 out of 6 physical characteristics. These findings highlight the subjective and potentially biased nature associated with coach rating systems and a lack of ability to differentiate between performers of similar abilities (Meylan *et al.*, 2010; Unnithan *et al.*, 2012). Or, raises question regarding generic physical fitness tests to assess characteristics appropriate to successful soccer performance.

Whilst **Chapter 3** of this thesis provided a cross-sectional approach to examine the discriminative ability of physical performance tests across a range of abilities, **Chapter 6** of this thesis examined association of player entry to an academy alongside physical performance scores relative to youth-senior transition, across 12 years. Despite previous propositions of the importance of early recruitment and specialisation (le Gall *et al.*, 2010; Meylan *et al.*, 2010), individuals recruited at an earlier age did not display higher probability of success in attaining a professional contract. Whilst small sample numbers present at both ends of the age spectrum may have influenced our results regarding successful vs. unsuccessful player outcomes, these findings are supported by the fact that 68% of successful players, within our sample, were recruited at age 12-years onwards. These findings align with recent research by Hertzog *et al.* (2018) and Güllich (2014) suggesting that early-stage recruitment has poor success rates regarding youth-senior transition, and, that the physical

and biological developments experienced across adolescence limits ability to identify and assess child and early-adolescent soccer players via physical performance testing with sufficient accuracy. The second main finding of **Chapter 6** of this thesis is that “successful” academy graduates were only observed to physically outperform their “unsuccessful” counterparts from ~13-14 years of age onward, with either no differences in performance, or, performance on physical fitness tests favouring “unsuccessful” players prior to this age. These findings further support the notion that high achievers during childhood and early adolescence may not translate into successful senior professionals and raise question towards predictive and early specialisation models of TI.

7.2.2 Physical fitness testing as part of the TD process

A reiterate theme throughout this thesis is that measures must provide accurate and meaningful data to thereby influence the training process. Consequently, with regards to TD strategies in youth soccer, tests should be validated and deemed appropriate for all individuals that they intend to assess. Findings from this thesis expanded upon the quality of information provided by commonly implemented fitness test measures. During **Chapter 3** of this thesis, the reliability of a comprehensive range of commonly-used field based fitness tests was assessed. Whilst most measures demonstrated adequate reliability (signal to noise ratio) for assessment across the entire age spectrum recruited within this study, the COD tests included within the battery were less reliable for younger participants (U11-U13). However, COD performance was one of the strongest contributors to “identified” vs. “unidentified” discrimination within this study, thus stressing its importance within the physical testing battery. Consequently, **Chapter 4** of this thesis was conducted to evaluate reliability of

alternative COD tests alongside examining reliability of an agility test due to its association to COD factors and alignment to sporting demands. In addition, this chapter aimed to assess relationships between various characteristics associated with agility performance, to identify characteristics most closely aligned with agility for implementation if COD and agility cannot be reliably measured within younger populations. Whilst this chapter demonstrated improved reliability comparative to that observed during **Chapter 3**, relationships were observed between younger and less mature individuals and between-day variance in performance on COD and agility tests. Whilst the tests selected within **Chapter 4** may provide more reliable means of assessment for these characteristics, the appropriateness of COD and agility tests within younger and immature populations could be questioned. Short distance linear sprint and COD performance largely related with agility performance within this sample, with a lower body reaction time test demonstrating small relationships. This chapter demonstrated stronger relationships between physical factors and agility comparative to previous research in senior athletes (Gabbett & Benton, 2009; Scanlan *et al.*, 2014; Sheppard *et al.*, 2006). Moreover, the importance of reaction time and cognitive factors relative to agility performance has also been advocated in adult populations (Naylor & Greig, 2015; Scanlan *et al.*, 2014; Spiteri *et al.*, 2013). Our findings, however, highlight the importance of physical factors for individuals who may lack cognitive and perceptual maturity and experience required to utilise these qualities during agility performance (Paul *et al.*, 2016).

7.3 Practical implications

Novel findings from this thesis provide several points of interest for practical application, potentially developing upon quality and accuracy of applied practice. **Chapter 3** of this thesis

suggests that whilst a physical fitness testing battery may discriminate between distinct population groups, it may lack sensitivity to differentiate between homogenous player groups (development vs. performance). This finding reiterates the importance of a multi-disciplinary testing battery for practical implementation when considering discrimination between academy and fringe players (Forsman *et al.*, 2016; Vaeyens *et al.*, 2006, 2008). However, these findings highlight potential limitations when basing decision making solely on physical performance test results in more homogenous player groups (Burgess & Naughton, 2010; Meylan *et al.*, 2010; Unnithan *et al.*, 2012). Another practical implication from **Chapter 3** is the potentially lower reliability of COD tests within younger soccer players. Commonly, as described during **Section 2.3** of this thesis, a range of physical measures are conducted within a performance testing battery, to assess the multitude of physical requirements relevant to soccer performance. However, findings from this chapter suggest that measures of COD performance may not be suitable for implementation in a young, immature sample. Considering the importance of COD qualities to differentiate between unidentified and identified players demonstrated within findings from **Chapter 3**, reliability of alternative COD and agility tests were assessed during **Chapter 4**. It was suggested that the physical complexity and demands on eccentric strength qualities of the tests selected within **Chapter 3** may have influenced the lower reliability observed (Lloyd *et al.*, 2013; Taylor *et al.*, 2018; Vandendriessche *et al.*, 2012). Consequently, tests deemed to be less demanding in these areas were selected for implementation during **Chapter 4**. The improved reliability observed suggests that the COD and agility measures from **Chapter 4** (m505COD, Y-SprintPRE) may be more suitable alternatives for examining COD qualities. However, the observed relationship between age/maturity status again question the value of testing these qualities in a young and immature sample. This should be discussed and considered by practitioners when

conducting physical testing batteries on these groups of players. Acknowledging this, the very strong relationships observed between COD/linear sprint ability and agility performance identifies characteristics that can be developed and assessed in absence of a reliable measure of COD performance.

Findings from **Chapter 5** of this thesis follow on from suggestions raised initially during **Chapter 3** around the ability of physical performance testing to differentiate between homogenous groups of soccer players. Ability of coaches to display reasonable accuracy when rating highest/lowest performers during this study suggests that coach rating systems may have a place within TI assessments attempting to differentiate between distinct player groups (Fenner *et al.*, 2016; Unnithan *et al.*, 2012; Williams & Reilly, 2000). However, the large amount of performance variance captured within each rating point demonstrates the disparity between subjective coach perception of ability and objective performance. Coaches and practitioners should, therefore, consider this discrepancy when adopting these methodologies. Finally, **Chapter 6** of this thesis provides several points potentially of interest for practical application. Considering the proclaimed relevance to longitudinal data to provide meaningful information around TI and TD from individuals making successful transition from youth-senior soccer (Gonaus & Müller, 2012; le Gall *et al.*, 2010; Williams & Reilly, 2000), and importance of early recruitment to subsequent success (Larkin & O'Connor, 2017; Unnithan *et al.*, 2012; Wrigley *et al.*, 2014), this chapter suggests that rate of development opposed early-recruitment and initial ability is of importance to youth-senior progression. Consequently, **Chapter 6** of this thesis suggest that coaches and practitioners should refrain from basing selection and recruitment decisions on isolated physical performance during childhood and early-adolescence. Moreover, findings from this chapter suggest that appropriate monitoring and evaluation processes would be of value as player's progress

through and academy, and, that rate of physical development across the duration of academy soccer may provide meaningful information relative to subsequent youth-senior progression.

7.4 Directions for future research

Despite some of the novel contributions to the literature presented in this thesis, the enormity of TI and TD eludes to many further research questions and avenues of study. **Chapter 3** of this thesis evaluated the discriminative ability of a comprehensive battery of field-based fitness tests to differentiate between identified vs. unidentified players. Throughout this thesis, the importance and value of a multi-disciplinary approach to TI has been reiterated (Sections 2.1.1, 2.1.3; Huijgen *et al.*, 2014; Reilly *et al.*, 2000). Whilst it is suggested from findings from this chapter that the selected battery discriminated between these distinct groups with ~70% accuracy, minimal differences were observed between development vs. performance players. These findings suggest that generic physical ability does not differentiate between these two distinct playing standards, and, therefore, additional characteristics must explain these differences. Despite the acknowledged difficulty with collecting meaningful multi-disciplinary data, future research should attempt to evaluate multiple playing standards within a governing body infrastructure adopting a multi-disciplinary approach. Both **Chapters 3 & 4** identified the potential lower reliability of COD tests within young, immature samples. Consequently, findings from these chapters suggest further research be directed towards further exploring the influence of age and maturity status on reliability of measures, specifically those demanding prerequisites of movement and motor skills or strength levels. Similarly, **Chapter 4** of this thesis observed small to moderate relationships between the LBRTT and agility performance, despite previous reports that measures of reaction time and perceptual-cognitive ability best relate to agility performance

in senior athletes (Naylor & Greig, 2015; Scanlan *et al.*, 2014; Spiteri *et al.*, 2013). As a result, we suggest that these characteristics may not be developed or experienced enough to substantially contribute to agility performance. Therefore, further research is warranted evaluating the development of reactive and perceptual-cognitive characteristics within youth athletes. Findings from **Chapter 5** of this thesis suggest that relationships between subjective coach-rating and objective fitness test performance are skewed in nature, accurate only for highest and lowest performers within a group of youth soccer players. A suggested limitation of this study was the ability of a generic fitness test to capture the characteristics captured during soccer performance, rated by coaches. Accordingly, future research should consider evaluating relationships between either; generic physical fitness test performance and in-game metrics gathered via GPS metrics or observational notations, or between; in-game metrics and coach subjective rating of ability. Finally, **Chapter 6** of this thesis examined association of player entry to an academy alongside physical performance scores relative to youth-senior transition, in a longitudinal design, across 12 years. Similar to ability to collect multi-disciplinary data, difficulties of capacity to collect longitudinal data have been noted throughout this thesis (Sections 2.1.1, 2.1.3; Sarmiento, Anguera, *et al.*, 2018; Vaeyens *et al.*, 2008). Whilst this study evaluated successful vs. unsuccessful players regarding youth-senior transition at the current club, it is unknown if some unsuccessful players successfully progressed to senior soccer within another club. Therefore, future research should strive to collect a more comprehensive range of variables within a longitudinal design, and, gain access to player records from an overarching governing body ensuring successful player outcomes, do not go amiss.

7.5 Conclusion

This thesis aimed to obtain a better understanding of the value of physical fitness testing within the TI and TD process of youth soccer players. The studies in this thesis have explored the validity of physical fitness testing as a method to contribute towards TI and TD processes. This thesis explored: 1) discriminative ability of physical fitness testing to differentiate between varied playing standards of youth soccer players; 2) suitability of various commonly used methods to reliably assess broad age and maturity levels of youth soccer players, 3) ability of physical fitness test performance to provide accurate and representative information relative to soccer performance and success, and; 4) the extent to which physical fitness test performance aligns with coach perception of ability and rating. The studies presented in this thesis will allow coaches and practitioners to make more educated and informed decisions when using routinely collected fitness test data, considerably add to the body of research in the area, and provide suggestions for future research to further educate on TI and TD in youth soccer. This thesis concludes the following:

1. Physical fitness testing can provide useful information towards TI processes, however, should not be used in isolation due to a lack of ability to discriminate between homogenous groups of youth soccer players.
2. Some fitness test measures, specifically those requiring prerequisites of strength and movement competency, may be less reliable for chronologically younger and biologically less mature players.
3. Physical fitness testing may not completely align with coach perception of ability, further reiterating the needs for a diverse and multi-disciplinary approach when utilising these methods in youth soccer players.

4. Rate of development opposed to early specialisation or ability appears to be more influential when considering successful youth-senior progression.

REFERENCES

- Abbott, A., Button, C., Pepping, G., & Collins, D. (2005). Unnatural selection: Talent identification and development in sport. *Nonlinear Dynamics, Psychology, and Life Sciences*, 9(1), 61–88.
- Abbott, A., & Collins, D. (2002). A theoretical and empirical analysis of a “state of the art” talent identification model. *High Ability Studies*, 13(2), 157–178.
<https://doi.org/10.1080/135981302200004879>
- Abbott, A., & Collins, D. (2004). Eliminating the dichotomy between theory and practice in talent identification and development: Considering the role of psychology. *Journal of Sports Sciences*, 22(5), 395–408. <https://doi.org/10.1080/02640410410001675324>
- Abdullah, M. R., Musa, R. M., Maliki, A. B. H. M. B., Kosni, N. A., & Suppiah, P. K. (2016). Role of psychological factors on the performance of elite soccer players. *Journal of Physical Education and Sport*, 16(1), 170–176. <https://doi.org/10.7752/jpes.2016.01027>
- Abt, G., & Lovell, R. (2009). The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. *Journal of Sports Sciences*, 27(9), 893–898. <https://doi.org/10.1080/02640410902998239>
- ACSM. (2006). *ACSM Guidelines for Exercise Testing and Prescription* (7th editio). Philadelphia: Lippincott Williams & Wilkins.
- Akenhead, R., French, D., Thompson, K. G., & Hayes, P. R. (2014). The acceleration dependent validity and reliability of 10Hz GPS. *Journal of Science and Medicine in Sport*, 17(5), 562–566. <https://doi.org/10.1016/j.jsams.2013.08.005>
- Akenhead, R., Hayes, P. R., Thompson, K. G., & French, D. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport*, 16(6), 556–561. <https://doi.org/10.1016/j.jsams.2012.12.005>
- Al Haddad, H., Simpson, B. M., & Buchheit, M. (2015). Monitoring changes in jump and sprint performance: Best or average values? *International Journal of Sports Physiology and Performance*, 10(7), 931–934. <https://doi.org/10.1123/ijssp.2014-0540>
- Ali, A. (2011). Measuring soccer skill performance: A review. *Scandinavian Journal of Medicine and Science in Sports*, 21(2), 170–183. <https://doi.org/10.1111/j.1600-0838.2010.01256.x>
- Almeida, C. H., Duarte, R., Volossovitch, A., & Ferreira, A. P. (2016). Scoring mode and age-related effects on youth soccer teams’ defensive performance during small-sided games. *Journal of*

- Sports Sciences*, 34(14), 1355–1362. <https://doi.org/10.1080/02640414.2016.1150602>
- Altmann, S., Hoffmann, M., Kurz, G., Neumann, R., Woll, A., & Haertel, S. (2015). Different Starting Distances Affect 5-m Sprint Times. *Journal of Strength and Conditioning Research*, 29(8), 2361–2366. <https://doi.org/10.1519/JSC.0000000000000865>
- Amaral, J. F., Mancini, M., & Novo Júnior, J. M. (2012). Comparison of three hand dynamometers in relation to the accuracy and precision of the measurements. *Revista Brasileira de Fisioterapia*, 16(3), 216–224. <https://doi.org/10.1590/S1413-35552012000300007>
- Anderson, L., Orme, P., Di Michele, R., Close, G. L., Milsom, J., Morgans, R., ... Morton, J. P. (2016). Quantification of seasonal-long physical load in soccer players with different starting status from the English premier league: Implications for maintaining squad physical fitness. *International Journal of Sports Physiology and Performance*, 11(8), 1038–1046. <https://doi.org/10.1123/ijsp.2015-0672>
- Andrzejewski, M., Chmura, J., Pluta, B., Strzelczyk, R., & Kasprzak, A. (2013). Analysis of sprinting activities of professional soccer players. *Journal of Strength and Conditioning Research*, 27(8), 2134–2140. <https://doi.org/10.1519/JSC.0b013e318279423e>
- Aquino, R., Alves, I. S., Padilha, M. B., Casanova, F., Puggina, E. F., & Maia, J. (2017). Multivariate Profiles of Selected Versus non-Selected Elite Youth Brazilian Soccer Players. *Journal of Human Kinetics*, 60(1), 113–121. <https://doi.org/10.1515/hukin-2017-0094>
- Askling, C., Karlsson, J., & Thorstensson, A. (2003). Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scandinavian Journal of Medicine and Science in Sports*, 13(4), 244–250. <https://doi.org/10.1034/j.1600-0838.2003.00312.x>
- Association, T. F. (2018). New Plans for 2018. Retrieved December 5, 2018, from <http://www.thefa.com/news/2018/01/09/09/02/fa-announces-new-plans-and-investments-for-2018-090118>
- Atkinson, G., & Nevill, A. M. (1998). Statistical Methods for Asssing Measurement Error (Reliability) in Variables Relevant to Sports Medicine. *Sports Medicine*, 26(4), 217–238.
- Baker, J., Schorer, J., & Wattie, N. (2018). Compromising Talent: Issues in Identifying and Selecting Talent in Sport. *Quest*, 70(1), 48–63. <https://doi.org/10.1080/00336297.2017.1333438>
- Bangsbo, J. (1994). The physiology of soccer-with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica*, 619, 1–155.

- Bangsbo, J., Iaia, F. M., & Krstrup, P. (2008). The Yo-Yo Intermittent Recovery Test - A Useful Tool for Evaluation of Physical Performance in Intermittent Sports. *Medicine & Science in Sports & Exercise*, *38*(1), 37–51.
- Bangsbo, J., Mohr, M., & Krstrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, *24*(7), 665–674.
<https://doi.org/10.1080/02640410500482529>
- Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The Evolution of Physical and Technical Performance Parameters in the English Premier League. *International Journal of Sports Medicine*, *35*, 1095–1100. <https://doi.org/10.1055/s-0034-1375695>
- Baxter-Jones, A. D. G. (1995). Growth and development of young athletes: Should competition levels be age related? *Sports Medicine*, *20*(2), 59–64. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/7481282>
- Bazyler, C. D., Beckham, G. K., & Sato, K. (2015). The use of the isometric squat as a measure of strength and explosiveness. *Journal of Strength and Conditioning Research*, *29*(5), 1386–1392.
- Behringer, M., Vom Heede, A., Matthews, M., & Mester, J. (2011). Effects of strength training on motor performance skills in children and adolescents: a meta-analysis. *Pediatric Exercise Science*, *23*(2), 186–206. <https://doi.org/10.1186/1471-2393-11-66>
- Bergkamp, T. L. G., Niessen, A. S. M., Den Hartigh, R. J. R., Frencken, W. G. P., & Meijer, R. R. (2019). Methodological Issues in Soccer Talent Identification Research: A Critical Review. *Sports Medicine*, *8*(6). <https://doi.org/10.1007/s40279-019-01113-w>
- Bishop, C., Turner, A., & Read, P. (2018). Effects of inter-limb asymmetries on physical and sports performance: a systematic review. *Journal of Sports Sciences*, *36*(10), 1135–1144.
<https://doi.org/10.1080/02640414.2017.1361894>
- Bloomfield, J., Polman, R., Butterly, R., & O'Donoghue, P. (2005). Analysis of age, stature, body mass, BMI and quality of elite soccer players from 4 European leagues. *Journal of Sports Medicine and Physical Fitness*, *45*, 58–67.
- Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical demands of different positions in FA Premier League soccer. *Journal of Sports Science and Medicine*, *6*(1), 63–70.
<https://doi.org/www.jssm.org>
- Borges, P. H., Cumming, S., Ronque, E. R. V., Cardoso, F., Avelar, A., Rechenchosky, L., ... Rinaldi, W. (2018). Relationship between Tactical Performance, Somatic Maturity and Functional

- Capabilities in Young Soccer Players. *Journal of Human Kinetics*, 64(1), 160–169.
<https://doi.org/10.1515/hukin-2017-0190>
- Bradley, P. S., Carling, C., Archer, D., Roberts, J., Dodds, A., di Mascio, M., ... Krstrup, P. (2011). The effect of playing formation on high-intensity running and technical profiles in English FA premier League soccer matches. *Journal of Sports Sciences*, 29(8), 821–830.
<https://doi.org/10.1080/02640414.2011.561868>
- Brownlee, T. E., Murtagh, C. F., Naughton, R. J., Whitworth-Turner, C. M., O’Boyle, A., Morgans, R., ... Drust, B. (2018). Isometric maximal voluntary force evaluated using an isometric mid-thigh pull differentiates English Premier League youth soccer players from a maturity-matched control group. *Science and Medicine in Football*, 2(3), 209–215.
<https://doi.org/10.1080/24733938.2018.1432886>
- Brustio, P. R., Lupo, C., Ungureanu, A. N., Frati, R., Rainoldi, A., & Boccia, G. (2018). The relative age effect is larger in Italian soccer top-level youth categories and smaller in Serie A. *PLoS ONE*, 13(4), 1–12. <https://doi.org/10.1371/journal.pone.0196253>
- Buchheit, M. (2008). The 30-15 Intermittent Fitness Test: Accuracy for Individualizing Interval Training of Young Intermittent Sport Players. *Journal of Strength and Conditioning Research*, 22(2), 365–374. <https://doi.org/10.3141/1747-08>
- Buchheit, M. (2014). Monitoring training status with HR measures: Do all roads lead to Rome? *Frontiers in Physiology*, 5 FEB(February), 1–19. <https://doi.org/10.3389/fphys.2014.00073>
- Buchheit, M., Haddad, H. Al, Simpson, B. M., Palazzi, D., Bourdon, P. C., Salvo, V. Di, & Mendez-Villanueva, A. (2014). Monitoring accelerations with gps in football: Time to slow down. *International Journal of Sports Physiology and Performance*, 9(3), 442–445.
<https://doi.org/10.1123/IJSP.2013-0187>
- Buchheit, M., & Mendez-Villanueva, A. (2014). Effects of age, maturity and body dimensions on match running performance in highly trained under-15 soccer players. *Journal of Sports Sciences*, 32(13), 1271–1278. <https://doi.org/10.1080/02640414.2014.884721>
- Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., & Bourdon, P. C. (2010). Match Running Performance and Fitness in Youth Soccer. *International Journal of Sports Medicine*, 31, 818–825.
- Buchheit, M., Simpson, B. M., Peltola, E., & Mendez-Villanueva, A. (2012). Assessing maximal sprinting speed in highly trained young soccer players. *International Journal of Sports*

- Physiology and Performance*, 7(1), 76–78. <https://doi.org/10.1123/ijsp.7.1.76>
- Burgess, D. J., & Naughton, G. A. (2010). Talent Development in Adolescent Team Sports : A Review. *International Journal of Sports Physiology and Performance*, 5, 103–116.
- Bush, M., Barnes, C., Archer, D. T., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Human Movement Science*, 39, 1–11. <https://doi.org/10.1016/j.humov.2014.10.003>
- Carling, C., Bloomfield, J., Nelson, L., & Reilly, T. (2008). The role of motion analysis in elite soccer. *Sports Medicine*, 38(10), 839–862.
- Carling, C., Le Gall, F., & Malina, R. M. (2012). Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003. *Journal of Sports Sciences*, 30(15), 1683–1693. <https://doi.org/10.1080/02640414.2011.637950>
- Carling, C., Le Gall, F., Reilly, T., & Williams, A. M. (2009). Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players? *Scandinavian Journal of Medicine and Science in Sports*, 19(1), 3–9. <https://doi.org/10.1111/j.1600-0838.2008.00867.x>
- Castagna, C., Impellizzeri, F., Cecchini, E., Rampinini, E., & Barbero Alvarez, J. C. (2009). Effects of Intermittent-Endurance Fitness on Match Performance in Young Male Soccer Players. *Journal of Strength and Conditioning Research*, 23(7), 1954–1959.
- Castagna, C., Impellizzeri, F., Chamari, K., Carlomagno, D., & Rampinini, E. (2006). Aerobic Fitness and Yo-Yo Continuous and Intermittent Tests Performances in Soccer Players: A Correlation Study. *Journal of Strength and Conditioning Research*, 20(2), 320–325.
- Castagna, C., Manzi, V., Impellizzeri, F., Weston, M., & Barbero Alvarez, J. C. (2010). Relationship between endurance field tests and match performance in young soccer players. *Journal of Strength and Conditioning Research*, 24(12), 3227–3233.
- Castagna, C., Varley, M., Póvoas, S. C. A., & D’Ottavio, S. (2017). Evaluation of the match external load in soccer: Methods comparison. *International Journal of Sports Physiology and Performance*, 12(4), 490–495. <https://doi.org/10.1123/ijsp.2016-0160>
- Chaabene, H., Prieske, O., Negra, Y., & Granacher, U. (2018). Change of Direction Speed: Toward a Strength Training Approach with Accentuated Eccentric Muscle Actions. *Sports Medicine*, 48(8), 1773–1779. <https://doi.org/10.1007/s40279-018-0907-3>

- Chamari, K., Chaouachi, A., Hambli, M., Fethi, K., Wisløff, U., & Castagna, C. (2008). The five-jump test for distance as a field test to assess lower limb explosive power in soccer players. *Journal of Strength and Conditioning Research*, 22(3), 944–950.
- Christensen, M. K. (2009). “An Eye for Talent”: Talent Identification and the “Practical Sense” of Top-Level Soccer Coaches. *Sociology of Sport Journal*, 26(3), 365–382.
<https://doi.org/10.1123/ssj.26.3.365>
- Claudino, J. G., Cronin, J., Mezêncio, B., McMaster, D. T., McGuigan, M., Tricoli, V., ... Serrão, J. C. (2017). The countermovement jump to monitor neuromuscular status: A meta-analysis. *Journal of Science and Medicine in Sport*, 20(4), 397–402. <https://doi.org/10.1016/j.jsams.2016.08.011>
- Coelho E Silva, M. J., Figueiredo, a. J., Simões, F., Seabra, a., Natal, a., Vaeyens, R., ... Malina, R. M. (2010). Discrimination of U-14 soccer players by level and position. *International Journal of Sports Medicine*, 31(11), 790–796. <https://doi.org/10.1055/s-0030-1263139>
- Colyer, S. L., Roberts, S. P., Robinson, J. B., Thompson, D., Stokes, K. A., Bilzon, J. L. J., & Salo, A. I. T. (2016). Detecting meaningful body composition changes in athletes using dual-energy x-ray absorptiometry. *Physiological Measurement*, 37(4), 596–609. <https://doi.org/10.1088/0967-3334/37/4/596>
- Comfort, P., Stewart, A., Bloom, L., & Clarkson, B. (2014). Relationships Between Strength, Sprint, and Jump Performance in Well-Trained Youth Soccer Players. *Journal of Strength and Conditioning Research*, 28(1), 173–177.
- Cook, G., Burton, L., & Hoogenboom, B. (2006). Pre-participation screening: The use of fundamental movements as an assessment of function - part 1. *North American Journal of Sports Physical Therapy*, 1(2), 62–72.
- Coutinho, P., Mesquita, I., & Fonseca, A. M. (2016). Talent development in sport: A critical review of pathways to expert performance. *International Journal of Sports Science & Coaching*, 11(2), 279–293. <https://doi.org/10.1177/1747954116637499>
- Cripps, A. J., Joyce, C., Woods, C. T., & Hopper, L. S. (2017). Biological maturity and the anthropometric, physical and technical assessment of talent identified U16 Australian footballers. *International Journal of Sports Science and Coaching*, 12(3), 344–350.
<https://doi.org/10.1177/1747954117710507>
- Cronin, J. B., & Templeton, R. L. (2008). Timing light height affects sprint times. *Journal of Strength and Conditioning Research*, 22(1), 318–320. <https://doi.org/10.1519/JSC.0b013e31815fa3d3>

- Cronin, J., & Sleivert, G. (2005). Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*, *35*(3), 213–234.
<https://doi.org/10.2165/00007256-200535030-00003>
- Cumming, S. P., Brown, D. J., Mitchell, S., Bunce, J., Hunt, D., Hedges, C., ... Malina, R. M. (2018). Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. *Journal of Sports Sciences*, *36*(7), 757–765.
<https://doi.org/10.1080/02640414.2017.1340656>
- Currell, K., & Jeukendrup, A. E. (2008). Validity, Reliability and Sensitivity of Measures of Sport Performance. *Sports Medicine*, *38*(4), 297–316.
- de Hoyo, M., Gonzalo-Skok, Ó., Sanudo, B., Carrascal, C., Plaza-Armas, J. R., Camacho-Candil, F., & Otero-Esquina, C. (2016). Comparative Effects of In-Season Full-Back Squat, Resisted Sprint Training, and Plyometric Training on Explosive Performance in U-19 Elite Soccer Players. *Journal of Strength and Conditioning Research*, *30*(2), 368–377.
- de Hoyo, M., Sañudo, B., Carrasco, L., Mateo-Cortes, J., Domínguez-Cobo, S., Fernandes, O., ... Gonzalo-Skok, O. (2016). Effects of 10-week eccentric overload training on kinetic parameters during change of direction in football players. *Journal of Sports Sciences*, *34*(14), 1380–1387.
<https://doi.org/10.1080/02640414.2016.1157624>
- Del Campo, D. G. D., Vicedo, J. C. P., Villora, S. G., & Jordan, O. R. C. (2010). The relative age effect in youth soccer players from Spain. *Journal of Sports Science and Medicine*, *9*, 190–198.
- Delorme, N., Boiché, J., & Raspaud, M. (2010). Relative age and dropout in French male soccer. *Journal of Sports Sciences*, *28*(7), 717–722. <https://doi.org/10.1080/02640411003663276>
- Deprez, D., Buchheit, M., Fransen, J., Pion, J., Lenoir, M., & Renaat, M. (2015). A Longitudinal Study Investigating the Stability of Anthropometry and Soccer-Specific Endurance in Pubertal High-Level Youth Soccer Players. *Journal of Sports Science and Medicine*, *14*(March), 418–426.
- Deprez, D., Coutts, A. J., Lenoir, M., Fransen, J., Pion, J., Philippaerts, R., & Vaeyens, R. (2014). Reliability and validity of the Yo-Yo intermittent recovery test level 1 in young soccer players. *Journal of Sports Sciences*, *32*(10), 903–910. <https://doi.org/10.1080/02640414.2013.876088>
- Deprez, D., Fransen, J., Boone, J., Lenoir, M., Philippaerts, R., & Vaeyens, R. (2014). Characteristics of high-level youth soccer players: variation by playing position. *Journal of Sports Sciences*, *33*(3), 243–254. <https://doi.org/10.1080/02640414.2014.934707>
- Deprez, D., Fransen, J., Lenoir, M., Philippaerts, R. M., & Vaeyens, R. (2015). The Yo-Yo intermittent

recovery test level 1 is reliable in young high-level soccer players. *Biology of Sport*, 32(1), 65–70. <https://doi.org/10.5604/20831862.1127284>

Deprez, D. N., Fransen, J., Lenoir, M., Philippaerts, R. M., & Vaeyens, R. (2015). A retrospective study on anthropometrical, physical fitness, and motor coordination characteristics that influence dropout, contract status, and first-team playing time in high-level soccer players aged eight to eighteen years. *Journal of Strength and Conditioning Research*, 29(6), 1692–1704.

Deprez, D., Valente-Dos-Santos, J., Coelho-E-Silva, M. J., Lenoir, M., Philippaerts, R., & Vaeyens, R. (2015). Longitudinal Development of Explosive Leg Power from Childhood to Adulthood in Soccer Players. *International Journal of Sports Medicine*, 36(8), 672–679. <https://doi.org/10.1055/s-0034-1398577>

Deprez, D., Valente-dos-Santos, J., Coelho e Silva, M., Lenoir, M., Philippaerts, R. M., & Vaeyens, R. (2014). Modeling developmental changes in the Yo-Yo Intermittent Recovery Test Level 1 in elite pubertal soccer players. *International Journal of Sports Physiology and Performance*, 9(6), 1006–1012. <https://doi.org/10.1123/ijsp.2013-0368>

Devlin, B. L., Leveritt, M. D., Kingsley, M., & Belski, R. (2017). Dietary intake, body composition, and nutrition knowledge of Australian football and soccer players: Implications for sports nutrition professionals in practice. *International Journal of Sport Nutrition and Exercise Metabolism*, 27(2), 130–138. <https://doi.org/10.1123/ijsnem.2016-0191>

Di Salvo, V., Baron, R., González-Haro, C., Gormasz, C., Pigozzi, F., & Bachl, N. (2010). Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *Journal of Sports Sciences*, 28(14), 1489–1494. <https://doi.org/10.1080/02640414.2010.521166>

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of high intensity activity in premier league soccer. *International Journal of Sports Medicine*, 30(3), 205–212. <https://doi.org/10.1055/s-0028-1105950>

Dodd, K. D., & Newans, T. J. (2018). Talent identification for soccer: Physiological aspects. *Journal of Science and Medicine in Sport*, 1–6. <https://doi.org/10.1016/j.jsams.2018.01.009>

Doncaster, G., Iga, J., & Unnithan, V. (2018). Assessing Differences in Cardiorespiratory Fitness With Respect to Maturity Status in Highly Trained Youth Soccer Players. *Pediatric Exercise Science*, 30(2), 216–228. <https://doi.org/10.1123/pes.2017-0185>

Doncaster, G., Scott, M., Iga, J., & Unnithan, V. (2018). Reliability of heart rate responses both during and following a 6 min Yo-Yo IR1 test in highly trained youth soccer players. *Science and*

Medicine in Football, 00(00), 1–7. <https://doi.org/10.1080/24733938.2018.1476775>

Dos'Santos, T., Thomas, C., Comfort, P., McMahon, J. J., & Jones, P. A. (2017). Relationships between Isometric Force-Time Characteristics and Dynamic Performance. *Sports*, 5(3), 68. <https://doi.org/10.3390/sports5030068>

Dos'Santos, T., Thomas, C., Jones, P. A., & Comfort, P. (2017). Mechanical Determinants of Faster Change of Direction Speed Performance in Male Athletes. *Journal of Strength and Conditioning Research*, 31(3), 696–705.

Draper, J. ., & Lancaster, M. . (1985). The 505 test: A test for agility in the horizontal plane. *Australian Journal of Science and Medicine in Sport*, 17(1), 15–18.

Drust, B., Waterhouse, J., Atkinson, G., Edwards, B., & Reilly, T. (2005). Circadian Rhythms in Sports Performance—an Update. *Chronobiology International*, 22(1), 21–44. Retrieved from <http://www.tandfonline.com/doi/full/10.1081/CBI-200041039>

Duthie, G. M., Pyne, D. B., Ross, A. A., Livingstone, S. G., & Hooper, S. L. (2006). The reliability of ten-meter sprint time using different starting techniques. *Journal of Strength and Conditioning Research*, 20(2), 246–251. <https://doi.org/10.1519/R-17084.1>

Earp, J. E., & Newton, R. U. (2012). Advances in Electronic Timing Systems: Considerations for Selecting an Appropriate Timing System. *Journal of Strength and Conditioning Research*, 26(5), 1245–1248.

Ehlert, A. M., Cone, J. R., Wideman, L., & Goldfarb, A. H. (2018). Evaluation of a Goalkeeper-Specific Adaptation to the Yo-Yo Intermittent Recovery Test Level 1: Reliability and Variability. *Journal of Strength and Conditioning Research*, 00(00), 1–6.

Emmonds, S., Till, K., Jones, B., Mellis, M., & Pears, M. (2016). Anthropometric, speed and endurance characteristics of English academy soccer players: Do they influence obtaining a professional contract at 18 years of age? *International Journal of Sports Science and Coaching*, 11(2), 212–218. <https://doi.org/10.1177/1747954116637154>

Enright, K., Morton, J., Iga, J., Lothian, D., Roberts, S., & Drust, B. (2017). Reliability of “in-season” fitness assessments in youth elite soccer players: a working model for practitioners and coaches. *Science and Medicine in Football*, 2(3), 1–7. <https://doi.org/10.1080/24733938.2017.1411603>

Fanchini, M., Castagna, C., Coutts, A. J., Schena, F., McCall, A., & Impellizzeri, F. M. (2014). Are the Yo-Yo intermittent recovery test levels 1 and 2 both useful? Reliability, responsiveness and

- interchangeability in young soccer players. *Journal of Sports Sciences*, 32(20), 1950–1957.
<https://doi.org/10.1080/02640414.2014.969295>
- Farrow, D., Young, W., & Bruce, L. (2005). The development of a test of reactive agility for netball: A new methodology. *Journal of Science and Medicine in Sport*, 8(1), 52–60.
[https://doi.org/10.1016/S1440-2440\(05\)80024-6](https://doi.org/10.1016/S1440-2440(05)80024-6)
- Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, 30(7), 625–631.
<https://doi.org/10.1080/02640414.2012.665940>
- Fenner, J. S. J., Iga, J., & Unnithan, V. (2016). The evaluation of small-sided games as a talent identification tool in highly trained prepubertal soccer players. *Journal of Sports Sciences*, 34(20), 1983–1990. <https://doi.org/10.1080/02640414.2016.1149602>
- FIFA. (2006). FIFA Big Count. Retrieved December 5, 2018, from
https://www.fifa.com/mm/document/fifafacts/bcoffsurv/bigcount.statspackage_7024.pdf
- Figueiredo, A. J., Coelho-e-Silva, M. J., Cumming, S. P., & Malina, R. M. (2018). Relative age effect: Characteristics of youth soccer players by birth quarter and subsequent playing status. *Journal of Sports Sciences*, 00(00), 1–8. <https://doi.org/10.1080/02640414.2018.1522703>
- Figueiredo, A. J., Gonçalves, C. E., Coelho e Silva, M. J., & Malina, R. M. (2009). Characteristics of youth soccer players who drop out, persist or move up. *Journal of Sports Sciences*, 27(9), 883–891. <https://doi.org/10.1080/02640410902946469>
- Figueiredo, A. J., Gonçalves, C. E., & Tessitore, A. (2014). Bridging the gap between empirical results, actual strategies, and developmental programs in soccer. *International Journal of Sports Physiology and Performance*, 9(3), 540–543. https://doi.org/10.1123/ijsp.2014_0023
- Fiorilli, G., Mitrotasios, M., Iuliano, E., Pistone, E. M., Aquino, G., Calcagno, G., & Di Cagno, A. (2016). Agility and change of direction in soccer: differences according to the player ages. *The Journal of Sports Medicine and Physical Fitness*, (May), 0–22.
- Ford, P., de Ste Croix, M., Lloyd, R., Meyers, R., Moosavi, M., Oliver, J., ... Williams, C. (2011). The Long-Term Athlete Development model: Physiological evidence and application. *Journal of Sports Sciences*, 29(4), 389–402. <https://doi.org/10.1080/02640414.2010.536849>
- Ford, P. R., Carling, C., Garces, M., Marques, M., Miguel, C., Farrant, A., ... Williams, A. M. (2012). The developmental activities of elite soccer players aged under-16 years from Brazil, England, France, Ghana, Mexico, Portugal and Sweden. *Journal of Sports Sciences*, 30(15), 1653–1663.

<https://doi.org/10.1177/1473225413492053>

- Ford, P. R., Ward, P., Hodges, N. J., & Mark Williams, A. (2009). The role of deliberate practice and play in career progression in sport: The early engagement hypothesis. *High Ability Studies*, 20(1), 65–75. <https://doi.org/10.1080/13598130902860721>
- Ford, P. R., & Williams, A. M. (2012). The developmental activities engaged in by elite youth soccer players who progressed to professional status compared to those who did not. *Psychology of Sport and Exercise*, 13(3), 349–352. <https://doi.org/10.1016/j.psychsport.2011.09.004>
- Forsman, H., Blomqvist, M., Davids, K., Liukkonen, J., & Konttinen, N. (2016). Identifying technical, physiological, tactical and psychological characteristics that contribute to career progression in soccer. *International Journal of Sports Science and Coaching*, 11(4), 505–513. <https://doi.org/10.1177/1747954116655051>
- Fragoso, I., Massuca, L. M., & Ferreira, J. (2015). Effect of Birth Month on Physical Fitness of Soccer Players (Under-15) According to Biological Maturity. *International Journal of Sports Medicine*, 36(1), 16–21. <https://doi.org/10.1055/s-0034-1384548>
- Fransen, J., French-Collier, N., Lenoir, M., Bennett, K. J. ., Deprez, D., Vaeyens, R., & Woods, C. T. (2017). Modelling age-related changes in motor competence and physical fitness in high-level youth soccer players: implications for talent identification and development. *Science and Medicine in Football*, 1(3), 203–208. <https://doi.org/10.1080/24733938.2017.1366039>
- Fransen, J., Philippaerts, R. M., Deprez, D., Pion, J., Lenoir, M., D'Hondt, E., ... Tallir, I. B. (2014). Changes in Physical Fitness and Sports Participation among Children with Different Levels of Motor Competence: A 2-Year Longitudinal Study. *Pediatric Exercise Science*, 26(1), 11–21. <https://doi.org/10.1123/pes.2013-0005>
- Fransen, J., Pion, J., Vandendriessche, J., Vandorpe, B., Vaeyens, R., Lenoir, M., & Philippaerts, R. M. (2012). Differences in physical fitness and gross motor coordination in boys aged 6-12 years specializing in one versus sampling more than one sport. *Journal of Sports Sciences*, 30(4), 379–386. <https://doi.org/10.1080/02640414.2011.642808>
- Fulcher, M. L., Hanna, C. M., & Raina Elley, C. (2010). Reliability of handheld dynamometry in assessment of hip strength in adult male football players. *Journal of Science and Medicine in Sport*, 13(1), 80–84. <https://doi.org/10.1016/j.jsams.2008.11.007>
- Furley, P., & Memmert, D. (2016). Coaches' implicit associations between size and giftedness: implications for the relative age effect. *Journal of Sports Sciences*, 34(5), 459–466.

<https://doi.org/10.1080/02640414.2015.1061198>

- Gabbett, T., & Benton, D. (2009). Reactive agility of rugby league players. *Journal of Science and Medicine in Sport, 12*(1), 212–214. <https://doi.org/10.1016/j.jsams.2007.08.011>
- Gabbett, T. J., Kelly, J. N., & Sheppard, J. M. (2008). Speed, change of direction speed, and reactive agility of rugby league players. *Journal of Strength and Conditioning Research, 22*(1), 174–181. <https://doi.org/10.1519/JSC.0b013e31815ef700>
- Gains, G. L., Swedenhjelm, A. N., Mayhew, J. L., Bird, H. M., & Houser, J. J. (2010). Comparison of speed and agility performance of college football players on field turf and natural grass. *Journal of Strength and Conditioning Research, 24*(10), 2613–2617. <https://doi.org/10.1519/JSC.0b013e3181eccdf8>
- Gaudino, P., Iaia, F. M., Alberti, G., Strudwick, A. J., Atkinson, G., & Gregson, W. (2013). Monitoring training in elite soccer players: Systematic bias between running speed and metabolic power data. *International Journal of Sports Medicine, 34*(11), 963–968. <https://doi.org/10.1055/s-0033-1337943>
- Gil, S. Ruiz, F. Irazusta, A. Gil, J. Irazusta, J. (2007). Selection of young soccer players in terms of anthropometric and physiological factors. *Journal of Sports Medicine and Physical Fitness, 47*, 25–32.
- Gil, S. M., Gil, J., Ruiz, F., Irazusta, A., & Irazusta, J. (2007). Physiological and anthropometric characteristics of young soccer players according to their playing position: Relevance for the selection process. *Journal of Strength and Conditioning Research, 21*(2), 438–445. <https://doi.org/10.1519/R-19995.1>
- Gil, S. M., Zabala-Lili, J., Bidaurrezaga-Letona, I., Aduna, B., Lekue, J. A., Santos-Concejero, J., & Granados, C. (2014). Talent identification and selection process of outfield players and goalkeepers in a professional soccer club. *Journal of Sports Sciences, 32*(20), 1931–1939. <https://doi.org/10.1080/02640414.2014.964290>
- Gissis, I., Papadopoulos, C., Kalapotharakos, V. I., Sotiropoulos, A., Komis, G., & Manolopoulos, E. (2006). Strength and Speed Characteristics of Elite, Subelite, and Recreational Young Soccer Players. *Research in Sports Medicine: An International Journal, 14*, 205–214.
- Gonaus, C., & Müller, E. (2012). Using physiological data to predict future career progression in 14- to 17-year-old Austrian soccer academy players. *Journal of Sports Sciences, 30*(15), 1673–1682. <https://doi.org/10.1080/02640414.2012.713980>

- González-Víllora, S., Pastor-Vicedo, J. C., & Cordente, D. (2015). Relative Age Effect in UEFA Championship Soccer Players. *Journal of Human Kinetics*, 47(1), 237–248.
<https://doi.org/10.1515/hukin-2015-0079>
- Goto, H., Morris, J. G., & Nevill, M. E. (2015). Match analysis of U9 and U10 english premier league academy soccer players using a global positioning system: Relevance for talent identification and development. *Journal of Strength and Conditioning Research*.
<https://doi.org/10.1519/JSC.0b013e3182a0d751>
- Gouvêa, M. A. De, Cyrino, E. S., Valente-Dos-Santos, J., Ribeiro, A. S., Silva, D. R. P. Da, Ohara, D., ... Ronque, E. R. V. (2017). Comparison of Skillful vs Less Skilled Young Soccer Players on Anthropometric, Maturation, Physical Fitness and Time of Practice. *International Journal of Sports Medicine*, 38(5), 384–395. <https://doi.org/10.1055/s-0042-122815>
- Gravina, L., Gil, S. M., Ruiz, F., Zubero, J., Gil, J., & Irazusta, J. (2008). Anthropometric and Physiological Differences Between First Team and Reserve Soccer Players Aged 10-14 at the Beginning and End of the Season. *Journal of Strength and Conditioning Research*, 22(4), 1308–1314.
- Grossmann, B., & Lames, M. (2015). From Talent to Professional Football – Youthism in German Football. *International Journal of Sports Science & Coaching*, 10(6), 1103–1113.
<https://doi.org/10.1260/1747-9541.10.6.1103>
- Güllich, A. (2014). Selection, de-selection and progression in German football talent promotion. *European Journal of Sport Science*, 14(6), 530–537.
<https://doi.org/10.1080/17461391.2013.858371>
- Harley, J. A., Barnes, C. A., Portas, M., Lovell, R., Barrett, S., Paul, D., & Weston, M. (2010). Motion analysis of match-play in elite U12 to U16 age-group soccer players. *Journal of Sports Sciences*, 28(13), 1391–1397. <https://doi.org/10.1080/02640414.2010.510142>
- Haugaasen, M., Toering, T., & Jordet, G. (2014). From childhood to senior professional football: elite youth players' engagement in non-football activities. *Journal of Sports Sciences*, 32(20), 1940–1949. <https://doi.org/10.1080/02640414.2014.970218>
- Haugen, T. A., Tønnessen, E., Svendsen, I. S., & Seiler, S. (2014). Sprint Time Difference Between Single- and Dual-Beam Timing Systems. *Journal of Strength and Conditioning Research*, 28(8), 2376–2379.
- Haugen, T., & Buchheit, M. (2016). Sprint Running Performance Monitoring: Methodological and

- Practical Considerations. *Sports Medicine*, 46(5), 641–656. <https://doi.org/10.1007/s40279-015-0446-0>
- Helsen, W. F., Baker, J., Michiels, S., Schorer, J., van Winckel, J., & Williams, A. M. (2012). The relative age effect in European professional soccer: Did ten years of research make any difference? *Journal of Sports Sciences*, 30(15), 1665–1671. <https://doi.org/10.1080/02640414.2012.721929>
- Helsen, W. F., Van Winckel, J., & Williams, A. M. (2005). The relative age effect in youth soccer across Europe. *Journal of Sports Sciences*, 23(6), 629–636. <https://doi.org/10.1080/02640410400021310>
- Hendry, D. T., & Hodges, N. J. (2018). Early majority engagement pathway best defines transitions from youth to adult elite men’s soccer in the UK: A three time-point retrospective and prospective study. *Psychology of Sport and Exercise*, 36(May 2017), 81–89. <https://doi.org/10.1016/j.psychsport.2018.01.009>
- Hendry, D. T., Williams, A. M., & Hodges, N. J. (2018). Coach ratings of skills and their relations to practice, play and successful transitions from youth-elite to adult-professional status in soccer. *Journal of Sports Sciences*, 00(00), 1–9. <https://doi.org/10.1080/02640414.2018.1432236>
- Henry, G. J., Dawson, B., Lay, B. S., & Young, W. B. (2013). Relationships between reactive agility movement time and unilateral vertical, horizontal, and lateral jumps. *Journal of Strength and Conditioning Research*, 30(9), 2514–2521. <https://doi.org/10.1519/JSC.0b013e3182a20ebc>
- Hertzog, M., Paul, D., Nassis, G., & Silva, J. (2018). Does Early Recruitment Predict Greater Physical Performance in Academy Soccer Players? *Sports*, 6(4), 108. <https://doi.org/10.3390/sports6040108>
- Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of Small-Sided Games Training. *Journal of Sports Medicine*, 41(3), 199–220. <https://doi.org/10.2165/11539740-000000000-00000>
- Hirose, N. (2009). Relationships among birth-month distribution, skeletal age and anthropometric characteristics in adolescent elite soccer players. *Journal of Sports Sciences*, 27(11), 1159–1166. <https://doi.org/10.1080/02640410903225145>
- Hoare, D. G., & Warr, C. R. (2000). Talent identification and women’s soccer: An Australian experience. *Journal of Sports Sciences*, 18(9), 751–758. <https://doi.org/10.1080/02640410050120122>
- Holt, N. L., & Dunn, J. G. H. (2004). Toward a grounded theory of the psychosocial competencies and

- environmental conditions associated with soccer success. *Journal of Applied Sport Psychology*, 16(3), 199–219. <https://doi.org/10.1080/10413200490437949>
- Höner, O., & Feichtinger, P. (2016). Psychological talent predictors in early adolescence and their empirical relationship with current and future performance in soccer. *Psychology of Sport and Exercise*, 25, 17–26. <https://doi.org/10.1016/j.psychsport.2016.03.004>
- Hopkins, W. G. (2000). Measures of Reliability in Sports Medicine and Science. *Sports Medicine*, 30(5), 375–381. <https://doi.org/10.2165/00007256-200030050-00006>
- Hopkins, W. G. (2002). A scale of magnitudes for effect statistics. Retrieved July 22, 2018, from <http://sportsci.org/resource/stats/effectmag.html>
- Hopkins, W. G., Hawley, J. A., & Burke, L. M. (1999). Design and analysis of research on sport performance enhancement. *Medicine & Science in Sports & Exercise*, 31(3), 472–485.
- Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, 41(1), 3–12. <https://doi.org/10.1249/MSS.0b013e31818cb278>
- Hughes, J. (2018). Sklar’s Omega: A Gaussian copula-based framework for assessing agreement. *ArXiv E-Prints*.
- Huijgen, B. C. H., Elferink-Gemser, M. T., Lemmink, K. A. P. M., & Visscher, C. (2014). Multidimensional performance characteristics in selected and deselected talented soccer players. *European Journal of Sport Science*, 14(1), 2–10. <https://doi.org/10.1080/17461391.2012.725102>
- Huijgen, B. C. H., Elferink-Gemser, M. T., Post, W. J., & Visscher, C. (2009). Soccer skill development in professionals. *International Journal of Sports Medicine*, 30(8), 585–591. <https://doi.org/10.1055/s-0029-1202354>
- Hulse, M. A., Morris, J. G., Hawkins, R. D., Hodson, A., Nevill, A. M., & Nevill, M. E. (2013). A field-test battery for elite, young soccer players. *International Journal of Sports Medicine*, 34(4), 302–311.
- Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., & Lubans, D. R. (2017). Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Preventive Medicine*, 95, 14–25. <https://doi.org/10.1016/j.ypmed.2016.11.027>

- Iacono, A. Dello, Martone, D., Cular, D., Milic, M., & Padulo, J. (2017). Game profile–based training in soccer: A new field approach. *Journal of Strength and Conditioning Research*, *31*(12), 3333–3342. <https://doi.org/10.1519/JSC.0000000000001768>
- Impellizzeri, F. M., Rampinini, E., Maffiuletti, N. A., Castagna, C., Bizzini, M., & Wisløff, U. (2008). Effects of aerobic training on the exercise-induced decline in short-passing ability in junior soccer players. *Applied Physiology, Nutrition, and Metabolism*, *33*(6), 1192–1198. <https://doi.org/10.1139/H08-111>
- Impellizzeri, F. M., Rampinini, E., & Marcora, S. M. (2005). Physiological assessment of aerobic training in soccer. *Journal of Sports Sciences*, *23*(6), 583–592. <https://doi.org/10.1080/02640410400021278>
- Ingebrigtsen, J., Dalen, T., Hjelde, G. H., Drust, B., & Wisløff, U. (2015). Acceleration and sprint profiles of a professional elite football team in match play. *European Journal of Sport Science*, *15*(2), 101–110. <https://doi.org/10.1080/17461391.2014.933879>
- Issurin, V. B. (2017). Evidence-Based Prerequisites and Precursors of Athletic Talent: A Review. *Sports Medicine*, *47*(10), 1993–2010. <https://doi.org/10.1007/s40279-017-0740-0>
- Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., & Aughey, R. J. (2010). The Validity and Reliability of GPS Units for Measuring Distance in Team Sport Specific Running Patterns. *International Journal of Sports Physiology and Performance*, *5*, 328–341. Retrieved from <https://opus.lib.uts.edu.au/bitstream/10453/16884/1/2010001370.pdf>
- Jimenez, I. P., & Pain, M. (2008). Relative age effect in Spanish association football: Its extent and implications for wasted potential. *Journal of Sports Sciences*, *26*(10), 995–1003. <https://doi.org/10.1080/02640410801910285>
- Johnson, A., Farooq, A., & Whiteley, R. (2017). Skeletal maturation status is more strongly associated with academy selection than birth quarter. *Science and Medicine in Football*, *1*(2), 157–163. <https://doi.org/10.1080/24733938.2017.1283434>
- Johnston, K., Wattie, N., Schorer, J., & Baker, J. (2018). Talent Identification in Sport: A Systematic Review. *Sports Medicine*, *48*(1), 97–109. <https://doi.org/10.1007/s40279-017-0803-2>
- Jullien, H., Bisch, C., Largouët, N., Manouvrier, C., Carling, C. J., & Amiard, V. (2008). Does a short period of lower limb strength training improve performance in field-based tests of running and agility in young professional soccer players. *Journal of Strength and Conditioning Research*, *22*(2), 404–411.

- Kannekens, R., Elferink-Gemser, M. T., & Visscher, C. (2011). Positioning and deciding: Key factors for talent development in soccer. *Scandinavian Journal of Medicine and Science in Sports*, 21(6), 846–852. <https://doi.org/10.1111/j.1600-0838.2010.01104.x>
- Keller, B. S., Raynor, A. J., Bruce, L., & Iredale, F. (2016). Technical attributes of Australian youth soccer players: Implications for talent identification. *International Journal of Sports Science and Coaching*, 11(6), 819–824. <https://doi.org/10.1177/1747954116676108>
- Kirkendall, D. T. (2014). The relative age effect has no influence on match outcome in youth soccer. *Journal of Sport and Health Science*, 3(4), 273–278. <https://doi.org/10.1016/j.jshs.2014.07.001>
- Kozieł, S. M., & Malina, R. M. (2018). Modified Maturity Offset Prediction Equations: Validation in Independent Longitudinal Samples of Boys and Girls. *Sports Medicine*, 48(1), 221–236. <https://doi.org/10.1007/s40279-017-0750-y>
- Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., ... Bangsbo, J. (2003). The Yo-Yo intermittent recovery test: Physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise*, 35(4), 697–705. <https://doi.org/10.1249/01.MSS.0000058441.94520.32>
- Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006). The Yo-Yo IR2 Test: Physiological Response, Reliability, and Application to Elite Soccer. *Medicine & Science in Sports & Exercise*, 38(9), 1666–1673. <https://doi.org/10.1519/JSC.0b013e318242a32a>
- Lago-Peñas, C., Rey, E., Lago-Ballesteros, J., Dominguez, E., & Casais, L. (2014). Seasonal variations in body composition and fitness parameters according to individual percentage of training. *International SportMed Journal*, 14(4), 205–215. Retrieved from <http://reference.sabinet.co.za/document/EJC146800>
- Larkin, P., & O'Connor, D. (2017). Talent identification and recruitment in youth soccer: Recruiter's perceptions of the key attributes for player recruitment. *PLoS ONE*, 12(4), 1–15. <https://doi.org/10.1371/journal.pone.0175716>
- Larkin, P., & Reeves, M. J. (2018). Junior-elite football: time to re-position talent identification? *Soccer and Society*, 19(8), 1183–1192. <https://doi.org/10.1080/14660970.2018.1432389>
- le Gall, F., Carling, C., Williams, M., & Reilly, T. (2010). Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *Journal of Science and Medicine in Sport*, 13(1), 90–95.
- Lee, M. J. C., Lloyd, D. G., Lay, B. S., Bourke, P. D., & Alderson, J. A. (2013). Effects of different visual

- stimuli on postures and knee moments during sidestepping. *Medicine and Science in Sports and Exercise*, 45(9), 1740–1748. <https://doi.org/10.1249/MSS.0b013e318290c28a>
- Lehance, C., Binet, J., Bury, T., & Croisier, J. L. (2009). Muscular strength, functional performances and injury risk in professional and junior elite soccer players. *Scandinavian Journal of Medicine and Science in Sports*, 19(2), 243–251. <https://doi.org/10.1111/j.1600-0838.2008.00780.x>
- Leite, N., Baker, J., & Sampaio, J. (2009). Paths to expertise in Portuguese national team athletes. *Journal of Sports Science and Medicine*, 8(4), 560–566.
- Leyhr, D., Kelava, A., Raabe, J., & Höner, O. (2018). Longitudinal motor performance development in early adolescence and its relationship to adult success: An 8-year prospective study of highly talented soccer players. *PLoS ONE*, 13(5), 1–16. <https://doi.org/10.1371/journal.pone.0196324>
- Leyk, D., Gorges, W., Ridder, D., Wunderlich, M., Rütger, T., Sievert, A., & Essfeld, D. (2007). Hand-grip strength of young men, women and highly trained female athletes. *European Journal of Applied Physiology*, 99(4), 415–421. <https://doi.org/10.1007/s00421-006-0351-1>
- Little, T., & Williams, A. G. (2005). Specificity of Acceleration, Maximum Speed, and Agility in Professional Soccer Players. *Journal of Strength and Conditioning Research*, 19(1), 76–78.
- Lloyd, R. S., & Oliver, J. L. (2012). The youth physical development model : A new approach to long-term athletic development. *Strength & Conditioning Journal*, 34(3), 61–72. <https://doi.org/10.1519/SSC.0b013e31825760ea>
- Lloyd, R. S., Oliver, J. L., Faigenbaum, A. D., Myer, G. D., & de Ste Croix, M. B. A. (2014). Chronological Age vs. Biological Maturation: Implications for Exercise Programming in Youth. *Journal of Strength and Conditioning Research*, 28(5), 1454–1464.
- Lloyd, R. S., Oliver, J. L., Radnor, J. M., Rhodes, B. C., Faigenbaum, A. D., & Myer, G. D. (2015). Relationships between functional movement screen scores, maturation and physical performance in young soccer players. *Journal of Sports Sciences*, 33(1), 11–19. <https://doi.org/10.1080/02640414.2014.918642>
- Lloyd, R. S., Read, P., Oliver, J. L., Meyers, R. W., Nimphius, S., & Jeffreys, I. (2013). Considerations for the Development of Agility During Childhood and Adolescence. *Strength and Conditioning Journal*, 35(3), 2–11. Retrieved from <http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00126548-201306000-00002>
- Lockie, R. G., Callaghan, S. J., & Jeffriess, M. D. (2013). Analysis of specific speed testing for

- cricketers. *Journal of Strength and Conditioning Research*, 27(11), 2981–2988.
- Loturco, I., Jeffreys, I., Cal Abad, C. C., Kobal, R., Zanetti, V., Pereira, L. A., & Nimphius, S. (2019). Change-of-direction, speed and jump performance in soccer players: a comparison across different age-categories. *Journal of Sports Sciences*, 00(00), 1–7. <https://doi.org/10.1080/02640414.2019.1574276>
- Lovell, R., Towlson, C., Parkin, G., Portas, M., Vaeyens, R., & Cobley, S. (2015). Soccer player characteristics in English lower-league development programmes: The relationships between relative age, maturation, anthropometry and physical fitness. *PLoS ONE*, 10(9), 1–14. <https://doi.org/10.1371/journal.pone.0137238>
- Lyle, M. A., Valero-Cuevas, F. J., Gregor, R. J., & Powers, C. M. (2015). Lower extremity dexterity is associated with agility in adolescent soccer athletes. *Scandinavian Journal of Medicine & Science in Sports*, 25(1), 81–88. <https://doi.org/10.1111/sms.12162>.Lower
- Malina, R. M. (2010). Early sport specialization: Roots, effectiveness, risks. *Current Sports Medicine Reports*, 9(6), 364–371. <https://doi.org/10.1249/JSR.0b013e3181fe3166>
- Malina, R. M., Cumming, S. P., Kontos, A. P., Eisenmann, J. C., Ribeiro, B., & Aroso, J. (2005). Maturity-associated variation in sport-specific skills of youth soccer players aged 13-15 years. *Journal of Sports Sciences*, 23(5), 515–522. <https://doi.org/10.1080/02640410410001729928>
- Malina, R. M., Figueiredo, A. J., & Coelho-e-Silva, M. J. (2017). Body Size of Male Youth Soccer Players: 1978–2015. *Sports Medicine*, 47(10), 1983–1992. <https://doi.org/10.1007/s40279-017-0743-x>
- Malina, R. M., Peña Reyes, M. E., Figueiredo, A. J., Coelho E Silva, M. J., Horta, L., Miller, R., ... Morate, F. (2010). Skeletal age in youth soccer players: Implication for age verification. *Clinical Journal of Sport Medicine*, 20(6), 469–474. <https://doi.org/10.1097/JSM.0b013e3181f827ea>
- Malina, R. M., Ribeiro, B., Aroso, J., & Cumming, S. P. (2007). Characteristics of youth soccer players aged 13-15 years classified by skill level. *British Journal of Sports Medicine*, 41(5), 290–295. <https://doi.org/10.1136/bjism.2006.031294>
- Malina, R. M., Rogol, A. D., Cumming, S. P., Coelho E Silva, M. J., & Figueiredo, A. J. (2015). Biological maturation of youth athletes: Assessment and implications. *British Journal of Sports Medicine*, 49(13), 852–859. <https://doi.org/10.1136/bjsports-2015-094623>
- Malone, J. J., Di Michele, R., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in elite English Premier League soccer players. *International Journal*

of Sports Physiology and Performance, 10(4), 489–497. <https://doi.org/10.1123/ijsp.2014-0352>

Malone, S., Hughes, B., Doran, D. A., Collins, K., & Gabbett, T. J. (2018). Can the workload–injury relationship be moderated by improved strength, speed and repeated-sprint qualities? *Journal of Science and Medicine in Sport*, 22(1), 29–34. <https://doi.org/10.1016/j.jsams.2018.01.010>

Markovic, G., & Mikulic, P. (2011). Discriminative ability of the yo-yo intermittent recovery test (level 1) in prospective young soccer players. *Journal of Strength and Conditioning Research*, 25(10), 2931–2934.

Martindale, R. J. J., Collins, D., & Abraham, A. (2007). Effective talent development: The elite coach perspective in UK sport. *Journal of Applied Sport Psychology*, 19(2), 187–206. <https://doi.org/10.1080/10413200701188944>

Martinez-Santos, R., Castillo, D., & Los Arcos, A. (2016). Sprint and jump performances do not determine the promotion to professional elite soccer in Spain, 1994–2012. *Journal of Sports Sciences*, 34(24), 2279–2285. <https://doi.org/10.1080/02640414.2016.1190460>

Matos, N., & Winsley, R. J. (2007). Trainability of young athletes and overtraining. *Journal of Sports Science and Medicine*, 6(September), 353–367.

McCunn, R., Weston, M., Hill, J. K. A., Johnston, R. D., & Gibson, N. V. (2017). Influence of Physical Maturity Status on Sprinting Speed Among Youth Soccer Players. *Journal of Strength and Conditioning Research*, 31(7), 1795–1801.

McGuigan, M. R., Newton, M. J., Winchester, J. B., & Nelson, A. G. (2010). Relationship Between Isometric and Dynamic Strength in Recreationally Trained Men. *Journal of Strength and Conditioning Research*, 24(9), 2570–2573.

McMaster, D. T., Gill, N., Cronin, J., & McGuigan, M. (2014). A brief review of strength and ballistic assessment methodologies in sport. *Sports Medicine*, 44(5), 603–623. <https://doi.org/10.1007/s40279-014-0145-2>

Memmert, D., Lemmink, K. A. P. M., & Sampaio, J. (2017). Current Approaches to Tactical Performance Analyses in Soccer Using Position Data. *Sports Medicine*, 47(1), 1–10. <https://doi.org/10.1007/s40279-016-0562-5>

Mendez-Villanueva, A., Buchheit, M., Kuitunen, S., Douglas, A., Peltola, E., & Bourdon, P. (2011). Age-related differences in acceleration, maximum running speed, and repeated-sprint performance in young soccer players. *Journal of Sports Sciences*, 29(5), 477–484.

<https://doi.org/10.1080/02640414.2010.536248>

- Mendez-Villanueva, A., Buchheit, M., Simpson, B., & Bourdon, P. C. (2013). Match play intensity distribution in youth soccer. *International Journal of Sports Medicine, 34*(2), 101–110. <https://doi.org/10.1055/s-0032-1306323>
- Meylan, C., Cronin, J., Oliver, J., & Hughes, M. (2010). Talent Identification in Soccer: The Role of Maturity Status on Physical, Physiological and Technical Characteristics. *International Journal of Sports Science & Coaching, 5*(4), 571–592. <https://doi.org/10.1260/1747-9541.5.4.571>
- Milsons, J., Naughton, R., O’Boyle, A., Iqbal, Z., Morgans, R., Drust, B., & Morton, J. P. (2015). Body composition assessment of English Premier League soccer players: a comparative DXA analysis of first team, U21 and U18 squads. *Journal of Sports Sciences, 33*(17), 1799–1806. <https://doi.org/10.1080/02640414.2015.1012101>
- Mirkov, D., Ugarkovic, D., Koprivica, V. J., & Jaric, S. (2015). Development of Anthropometric and Physical Performance Profiles of Young Elite Male Soccer Players: A Longitudinal Study. *Journal of Strength and Conditioning Research, 24*(10), 2677–2682.
- Mirwald, R. L., Baxter-Jones, A. D. G., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine & Science in Sports & Exercise, 34*(4), 689–694. <https://doi.org/10.1097/00005768-200204000-00020>
- Moir, G., Button, C., Glaister, M., & Stone, M. H. (2004). Influence of familiarization on the reliability of vertical jump and acceleration sprinting performance in physically active men. *Journal of Strength and Conditioning Research, 18*(2), 276–280.
- Moore, S. A., McKay, H. A., Macdonald, H., Nettlefold, L., Baxter-Jones, A. D. G., Cameron, N., & Brasher, P. M. A. (2015). Enhancing a somatic maturity prediction model. *Medicine and Science in Sports and Exercise, 47*(8), 1755–1764. <https://doi.org/10.1249/MSS.0000000000000588>
- Morgans, R., Orme, P., Anderson, L., & Drust, B. (2014). Principles and practices of training for soccer. *Journal of Sport and Health Science, 3*(4), 251–257. <https://doi.org/10.1016/j.jshs.2014.07.002>
- Morgans, R., Orme, P., Anderson, L., Drust, B., & Morton, J. P. (2014). An intensive winter fixture schedule induces a transient fall in salivary IgA in English premier league soccer players. *Research in Sports Medicine, 22*(4), 346–354. <https://doi.org/10.1080/15438627.2014.944641>
- Morland, B., Bottoms, L., Sinclair, J., & Bourne, N. (2013). Can change of direction speed and reactive agility differentiate female hockey players? *International Journal of Performance Analysis in*

Sport, 13(2), 510–521. Retrieved from <http://www.scopus.com/inward/record.url?eid=2-s2.0-84884259770&partnerID=tZOtx3y1>

Morley, D., Morgan, G., McKenna, J., & Nicholls, A. R. (2014). Developmental Contexts and Features of Elite Academy Football Players: Coach and Player Perspectives. *International Journal of Sports Science & Coaching*, 9(1), 217–232. <https://doi.org/10.1260/1747-9541.9.1.217>

Morrissey, M., Harman, E., & Johnson, M. (1995). Resistance training modes: specificity and effectiveness. *Medicine and Science in Sports and Exercise*, 27(5), 648–660.

Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *Journal of Sports Sciences*, 27(2), 107–114.

Mujika, I., Vaeyens, R., Matthys, S. P. J., Santisteban, J., Goirienea, J., & Philippaerts, R. (2009). The relative age effect in a professional football club setting. *Journal of Sports Sciences*, 27(11), 1153–1158. <https://doi.org/10.1080/02640410903220328>

Müller, L., Gehmaier, J., Gonaus, C., Raschner, C., & Müller, E. (2018). Maturity status strongly influences the relative age effect in international elite under-9 soccer. *Journal of Sports Science and Medicine*, 17(2), 216–222.

Murr, D., Feichtinger, P., Larkin, P., O'Connor, D., & Höner, O. (2018). Psychological talent predictors in youth soccer: A systematic review of the prognostic relevance of psychomotor, perceptual-cognitive and personality-related factors. *PLoS ONE*, 13(10). <https://doi.org/10.1371/journal.pone.0205337>

Murr, D., Raabe, J., & Höner, O. (2018). The prognostic value of physiological and physical characteristics in youth soccer: A systematic review. *European Journal of Sport Science*, 18(1), 62–74. <https://doi.org/10.1080/17461391.2017.1386719>

Murtagh, C. F., Brownlee, T. E., O'Boyle, A., Morgans, R., Drust, B., & Erskine, R. M. (2018). Importance of Speed and Power in Elite Youth Soccer Depends on Maturation Status. *Journal of Strength and Conditioning Research*, 32(2), 297–303. <https://doi.org/10.1519/JSC.0000000000002367>

Musculus, L., & Lobinger, B. H. (2018). Psychological characteristics in talented soccer players - Recommendations on how to improve coaches' assessment. *Frontiers in Psychology*, 9(FEB), 1–6. <https://doi.org/10.3389/fpsyg.2018.00041>

Naylor, J., & Greig, M. (2015). A hierarchical model of factors influencing a battery of agility tests. *The Journal of Sports Medicine and Physical Fitness*, 53, 160. Retrieved from

<http://www.ncbi.nlm.nih.gov/pubmed/25567047>

- Nimphius, S., Callaghan, S. J., Bezodis, N. E., & Lockie, R. G. (2018). Change of Direction and Agility Tests: Challenging Our Current Measures of Performance. *Strength and Conditioning Journal*, 40(1), 26–38. <https://doi.org/10.1519/SSC.0000000000000309>
- Nimphius, S., Callaghan, S. J., Spiteri, T., & Lockie, R. G. (2016). Change of Direction Deficit: A More Isolated Measure of Change of Direction Performance than Total 505 Time. *Journal of Strength and Conditioning Research*, 30(11), 3024–3032.
- Nimphius, S., Geib, G., Spiteri, T., & Carlisle, D. (2013). “Change of Direction Deficit” Measurement in Division I American Football Players. *Journal of Australian Strength and Conditioning*, 21(2), 115–117.
- Nimphius, S., McGuigan, M. R., & Newton, R. U. (2010). Relationship Between Strength, Power, Speed, and Change of Direction Performance of Female Softball Players. *Journal of Strength and Conditioning Research*, 24(4), 885–895.
- No, M., & Kwak, H.-B. (2016). Effects of environmental temperature on physiological responses during submaximal and maximal exercises in soccer players. *Integrative Medicine Research*, 5(3), 216–222. <https://doi.org/10.1016/j.imr.2016.06.002>
- O’Connor, D., Larkin, P., & Williams, A. M. (2016). Talent identification and selection in elite youth football: An Australian context. *European Journal of Sport Science*, 16(7), 837–844. <https://doi.org/10.1080/17461391.2016.1151945>
- Oliver, J. L., & Meyers, R. W. (2009). Reliability and generality of measures of acceleration, planned agility, and reactive agility. *International Journal of Sports Physiology and Performance*, 4(3), 345–354. <https://doi.org/10.1123/ijsp.4.3.345>
- Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: A new match analysis approach. *Medicine and Science in Sports and Exercise*, 42(1), 170–178. <https://doi.org/10.1249/MSS.0b013e3181ae5cfd>
- Ostojic, S. M. (2000). Physical and physiological characteristics of elite Serbian soccer players. *Physical Education & Sport*, 1(7), 23–29. Retrieved from <http://articles.sirc.ca/search.cfm?id=S-1032200%5Cnhttp://search.ebscohost.com/login.aspx?direct=true&db=sph&AN=SPHS-1032200&site=ehost-live%5Cnhttp://www.ni.ac.yu/Facta>
- Ostojic, S. M. (2003). Seasonal alterations in body composition and sprint performance of elite soccer players. *Journal of Exercise Physiology*, 6(3), 24–27.

<https://doi.org/10.1519/JSC.0b013e3181874564>

Ostojic, S. M. (2006). Estimation of body fat in athletes: Skinfolds vs bioelectrical impedance. *Journal of Sports Medicine and Physical Fitness*, 46(3), 442–446.

Ostojic, S. M., Castagna, C., Calleja-González, J., Jukic, I., Idrizovic, K., & Stojanovic, M. (2014). The biological age of 14-year-old boys and success in adult soccer: Do early maturers predominate in the top-level game? *Research in Sports Medicine*, 22(4), 398–407.
<https://doi.org/10.1080/15438627.2014.944303>

Otero-Esquina, C., de Hoyo Lora, M., Gonzalo-Skok, Ó., Domínguez-Cobo, S., & Sánchez, H. (2017). Is strength-training frequency a key factor to develop performance adaptations in young elite soccer players? *European Journal of Sport Science*, 17(10), 1241–1251.
<https://doi.org/10.1080/17461391.2017.1378372>

Owen, A. L., Lago-Peñas, C., Dunlop, G., Mehdi, R., Chtara, M., & Dellal, A. (2018). Seasonal Body Composition Variation Amongst Elite European Professional Soccer Players: An Approach of Talent Identification. *Journal of Human Kinetics*, 62(1), 177–184.
<https://doi.org/10.1515/hukin-2017-0132>

Padulo, J., Haddad, M., Ardigo, L. ., Chamari, K., & Pizzolato, F. (2015). High frequency performance analysis of professional soccer goalkeepers: A pilot study. *Journal of Sports Medicine and Physical Fitness*, 55(6), 557–562.

Palucci Vieira, L. H., Carling, C., Barbieri, F. A., Aquino, R., & Santiago, P. R. P. (2019). Match Running Performance in Young Soccer Players: A Systematic Review. *Sports Medicine*, 49(2), 289–318.
<https://doi.org/10.1007/s40279-018-01048-8>

Pankhurst, A., & Collins, D. (2013). Talent Identification and Development: The Need for Coherence Between Research, System, and Process. *Quest*, 65(1), 83–97.
<https://doi.org/10.1080/00336297.2012.727374>

Pastor-Vicedo, J. C., Contreras-Jordán, O., & Prieto-Ayuso, A. (2017). Performance indicators as a resource for the selection of talented football players. *Journal of Human Sport and Exercise*, 12(3proc), S797–S806. <https://doi.org/10.14198/jhse.2017.12.Proc3.03>

Paul, D. J., Gabbett, T. J., & Nassis, G. P. (2016). Agility in Team Sports: Testing, Training and Factors Affecting Performance. *Sports Medicine*, 46(3), 421–442. <https://doi.org/10.1007/s40279-015-0428-2>

Paul, D. J., & Nassis, G. P. (2015a). Physical Fitness Testing in Youth Soccer: Issues and Considerations

- Regarding Reliability, Validity, and Sensitivity. *Pediatric Exercise Science*, 27(3), 301–313.
Retrieved from <http://journals.humankinetics.com/doi/10.1123/pes.2014-0085>
- Paul, D. J., & Nassis, G. P. (2015b). Testing Strength and Power in Soccer Players: The Application of Conventional and Traditional Methods of Assessment. *Journal of Strength and Conditioning Research*, 29(6), 1748–1758.
- Pearson, D. T., Naughton, G. A., & Torode, M. (2006). Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. *Journal of Science and Medicine in Sport*, 9(4), 277–287. <https://doi.org/10.1016/j.jsams.2006.05.020>
- Pereira Da Silva, N., Kirkendall, D. T., & Leite De Barros Neto, T. (2007). Movement patterns in elite Brazilian youth soccer. *J Sports Med Phys Fitness*, 47(3).
- Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., ... Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences*, 24(3), 221–230.
- Phillips, E., Keith, D., Renshaw, I., & Portus, M. (2010). Expert performance in sport and the dynamics of talent development. *Sports Medicine*, 40(4), 271–283. <https://doi.org/10.1088/0031-9120/36/6/301>
- Pojksic, H., Åslin, E., Krolo, A., Jukic, I., Uljevic, O., Spasic, M., & Sekulic, D. (2018). Importance of reactive agility and change of direction speed in differentiating performance levels in junior soccer players: Reliability and validity of newly developed soccer-specific tests. *Frontiers in Physiology*, 9(MAY), 1–11. <https://doi.org/10.3389/fphys.2018.00506>
- Pyne, D. B., Spencer, M., & Mujika, I. (2014). Improving the value of fitness testing for football. *International Journal of Sports Physiology and Performance*, 9(3), 511–514.
<https://doi.org/10.1123/IJSP.2013-0453>
- Rabbani, A., Kargarfard, M., & Twist, C. (2018). Fitness Monitoring in Elite Soccer Players: Group vs. Individual Analyses. *Journal of Strength and Conditioning Research*, 00(00), 1–8.
- Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, 28(3), 228–235.
<https://doi.org/10.1055/s-2006-924340>
- Rampinini, E., Impellizzeri, F. M., Castagna, C., Azzalin, A., Bravo, D. F., & Wisløff, U. (2008). Effect of match-related fatigue on short-passing ability in young soccer players. *Medicine and Science in*

- Sports and Exercise*, 40(5), 934–942. <https://doi.org/10.1249/MSS.0b013e3181666eb8>
- Rampinini, E., Sassi, A., Azzalin, A., Castagna, C., Menaspà, P., Carlomagno, D., & Impellizzeri, F. M. (2010). Physiological determinants of Yo-Yo intermittent recovery tests in male soccer players. *European Journal of Applied Physiology*, 108(2), 401–409. <https://doi.org/10.1007/s00421-009-1221-4>
- Rebelo, A., Brito, J., Maia, J., Coelho-e-Silva, M. J., Figueiredo, A. J., Bangsbo, J., ... Seabra, A. (2013). Anthropometric Characteristics, Physical Fitness and Technical Performance of Under-19 Soccer Players by Competitive Level and Field Position. *International Journal of Sports Medicine*, 34(4), 312–317.
- Reeves, M. J., McRobert, A. P., Littlewood, M. A., & Roberts, S. J. (2018). A scoping review of the potential sociological predictors of talent in junior-elite football: 2000–2016. *Soccer and Society*, (February), 1–21. <https://doi.org/10.1080/14660970.2018.1432386>
- Reeves, M. J., Roberts, S. J., McRobert, A. P., & Littlewood, M. A. (2018). Factors affecting the identification of talented junior-elite footballers: a case study. *Soccer and Society*, (February), 1–16. <https://doi.org/10.1080/14660970.2018.1432383>
- Regnier, G., Salmela, J., & Russell, S. . (1993). *Talent detection and development in sport*. In R.N Singer, M.Murphy & L.K.Tennant (Eds.). New York: Macmillan.
- Reilly, T., George, K., Marfell-Jones, M., Scott, M., Sutton, L., & Wallace, J. A. (2009). How well do skinfold equations predict percent body fat in elite soccer players? *International Journal of Sports Medicine*, 30(8), 607–613. <https://doi.org/10.1055/s-0029-1202353>
- Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences*, 18(9), 695–702.
- Requena, B., González-Badillo, J. J., de Villareal, E. S. S., Erelina, J., García, I., Gapeyeva, H., & Pääsuke, M. (2009). Functional performance, maximal strength, and power characteristics in isometric and dynamic actions of lower extremities in soccer players. *Journal of Strength and Conditioning Research*, 23(5), 1391–1401.
- Rienzi, E., Drust, B., Reilly, T., Carter, J. E. ., & Martin, A. (2000). Investigation of anthropometric and work-rate profiles of elite South American international players. *Journal of Sports Medicine and Physical Fitness*, 40(2), 162–169.
- Roca, A., Williams, A. M., & Ford, P. R. (2012). Developmental activities and the acquisition of superior anticipation and decision making in soccer players. *Journal of Sports Sciences*, 30(15),

1643–1652. <https://doi.org/10.1080/02640414.2012.701761>

- Rommers, N., Mostaert, M., Goossens, L., Vaeyens, R., Witvrouw, E., Lenoir, M., & D'Hondt, E. (2018). Age and maturity related differences in motor coordination among male elite youth soccer players. *Journal of Sports Sciences*, *00*(00), 1–8. <https://doi.org/10.1080/02640414.2018.1488454>
- Rongen, F., Mckenna, J., Cobley, S., & Till, K. (2018). Are youth sport talent identification and development systems necessary and healthy? *Sports Medicine - Open*, *4*(18), 1–4. <https://doi.org/10.1186/s40798-018-0135-2>
- Rowat, O., Fenner, J., & Unnithan, V. (2017). Technical and physical determinants of soccer match-play performance in elite youth soccer players. *The Journal of Sports Medicine and Physical Fitness*, *57*(4), 369–379. <https://doi.org/10.23736/S0022-4707.16.06093-X>
- Rubajczyk, K., & Rokita, A. (2018). The Relative Age Effect in Poland's Elite Youth Soccer Players. *Journal of Human Kinetics*, *64*(1), 265–273. <https://doi.org/10.1515/hukin-2017-0200>
- Sarmento, H., Anguera, M. T., Pereira, A., & Araújo, D. (2018). Talent Identification and Development in Male Football: A Systematic Review. *Sports Medicine*, *48*(4), 907–931. <https://doi.org/10.1007/s40279-017-0851-7>
- Sarmento, H., Clemente, F. M., Harper, L. D., Costa, I. T. da, Owen, A., & Figueiredo, A. J. (2018). Small sided games in soccer – a systematic review. *International Journal of Performance Analysis in Sport*, *00*(00), 1–57. <https://doi.org/10.1080/24748668.2018.1517288>
- Saward, C., Morris, J. G., Nevill, M. E., Nevill, A. M., & Sunderland, C. (2016). Longitudinal development of match-running performance in elite male youth soccer players. *Scandinavian Journal of Medicine and Science in Sports*, *26*(8), 933–942. <https://doi.org/10.1111/sms.12534>
- Saward, C., Morris, J. G., Nevill, M. E., & Sunderland, C. (2018). The effect of playing status, maturity status, and playing position on the development of match skills in elite youth football players aged 11–18 years: A mixed-longitudinal study. *European Journal of Sport Science*, *0*(0), 1–12. <https://doi.org/10.1080/17461391.2018.1508502>
- Scanlan, A., Humphries, B., Tucker, P. S., & Dalbo, V. (2014). The influence of physical and cognitive factors on reactive agility performance in men basketball players. *Journal of Sports Sciences*, *32*(4), 367–374. <https://doi.org/10.1080/02640414.2013.825730>
- Schuth, G., Carr, G., Barnes, C., Carling, C., & Bradley, P. S. (2016). Positional interchanges influence the physical and technical match performance variables of elite soccer players. *Journal of*

- Sports Sciences*, 34(6), 501–508. <https://doi.org/10.1080/02640414.2015.1127402>
- Scott, B. R., Lockie, R. G., Knight, T. J., Clark, A. C., & De Jonge, X. A. K. J. (2013). A comparison of methods to quantify the in-season training load of professional soccer players. *International Journal of Sports Physiology and Performance*, 8(2), 195–202. <https://doi.org/10.1123/ijsp.8.2.195>
- Sekulic, D., Krolo, A., Spasic, M., Uljevic, O., & Peric, M. (2014). The development of a new stop'n'go reactive-agility test. *Journal of Strength and Conditioning Research*, 28(11), 3306–3312. <https://doi.org/10.1519/JSC.0000000000000515>
- Semenick, D. (1990). The T-test. *Journal of Strength and Conditioning Research*, 12(1), 36–37.
- Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, 24(9), 919–932. <https://doi.org/10.1080/02640410500457109>
- Sheppard, J. M., Young, W. B., Doyle, T. L. A., Sheppard, T. A., & Newton, R. U. (2006). An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed. *Journal of Science and Medicine in Sport*, 9(4), 342–349. <https://doi.org/10.1016/j.jsams.2006.05.019>
- Sieghartsleitner, R., Zuber, C., Zibung, M., & Conzelmann, A. (2019). Science or Coaches' Eye? – Both! Beneficial Collaboration of Multidimensional Measurements and Coach Assessments for Efficient Talent Selection in Elite Youth Football. *Journal of Sports Science and Medicine*, 32–43.
- Silvestre, R., West, C., Maresh, C. M., & Kraemer, W. J. (2006). Body composition and physical performance in men's soccer: A study of a National Collegiate Athletic Association Division I team. *Journal of Strength and Conditioning Research*, 20(1), 177–183. <https://doi.org/10.1519/R-17715.1>
- Spiteri, T., Cochrane, J. L., & Nimphius, S. (2012). Human stimulus reliability during an offensive and defensive agility protocol. *Journal of Australian Strength and Conditioning*, 20(4), 20–27. Retrieved from https://www.researchgate.net/profile/Tania_Spiteri/publication/230770444_Human_stimulus_reliability_during_an_offensive_and_defensive_agility_protocol/links/0fcfd5127895ee64bd000000.pdf
- Spiteri, T., Cochrane, J. L., & Nimphius, S. (2013). The Evaluation of a New Lower-Body Reaction Time Test. *Journal of Strength and Conditioning Research*, 27(1), 174–180.
- Spiteri, T., Newton, R. U., Binetti, M., Hart, N. H., Sheppard, J. M., & Nimphius, S. (2015). Mechanical

Determinants of Faster Change of Direction and Agility Performance in Female Basketball Athletes. *Journal of Strength and Conditioning Research*, 29(8), 2205–2214.

<https://doi.org/10.1002/9781118525975.ch9>

Spiteri, T., Nimphius, S., Hart, N. H., Specos, C., Sheppard, J. M., & Newton, R. U. (2014). Contribution of Strength Characteristics to Change of Direction and Agility Performance in Female Basketball Athletes. *Journal of Strength and Conditioning Research*, 28(9), 2415–2423.

Sporis, G., Jukic, I., Milanovic, L., & Vucetic, V. (2010). Reliability and factorial validity of agility tests for soccer players. *Journal of Strength and Conditioning Research*, 24(3), 679–686.

<https://doi.org/10.1519/JSC.0b013e3181c4d324>

Sporis, G., Jukic, I., Ostojic, S. M., & Milanovic, D. (2009). Fitness Profiling in Soccer: Physical and Physiologic Characteristics of Elite Players. *Journal of Strength and Conditioning Research*, 23(7), 1947–1953. <https://doi.org/10.1016/j.jsams.2011.03.012>

Statista. (2018a). Big-5 league soccer clubs ranked by combined transfer fee spending from 2010 to 2016. Retrieved December 5, 2018, from <https://www.statista.com/statistics/746666/big-5-soccer-league-clubs-ranked-by-combined-transfer-fee-spending/>

Statista. (2018b). Market size of the European professional football market from 2006/07 to 2016/17. Retrieved December 5, 2018, from <https://www.statista.com/statistics/261223/european-soccer-market-total-revenue/>

Stølen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of Soccer: An Update. *Sports Medicine*, 35(6), 501–536.

Stratton, G., Reilly, T., Williams, A. M., & Richardson, D. (2004). *Youth Soccer: From Science to Performance* (First edit). Routledge.

Strudwick, A., Reilly, T., & Doran, D. (2002). Anthropometric and fitness profiles of elite players in two codes. *Journal of Sports Medicine and Physical Fitness*, 42(2), 239–242.

Suarez-Arrones, L., Petri, C., Maldonado, R. A., Torreno, N., Munguía-Izquierdo, D., Di Salvo, V., & Méndez-Villanueva, A. (2018). Body fat assessment in elite soccer players: cross-validation of different field methods. *Science and Medicine in Football*, 2(3), 203–208.

<https://doi.org/10.1080/24733938.2018.1445871>

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine*, 46(10), 1419–1449. [https://doi.org/10.1007/s40279-016-0486-](https://doi.org/10.1007/s40279-016-0486-0)

0

- Sutton, L., Scott, M., Wallace, J., & Reilly, T. (2009). Body composition of English Premier League soccer players: Influence of playing position, international status, and ethnicity. *Journal of Sports Sciences, 27*(10), 1019–1026. <https://doi.org/10.1080/02640410903030305>
- Taylor, J. M., Cunningham, L., Hood, P., Thorne, B., Irvin, G., & Weston, M. (2018). The reliability of a modified 505 test and change-of-direction deficit time in elite youth football players. *Science and Medicine in Football, 00*(00), 1–6. <https://doi.org/10.1080/24733938.2018.1526402>
- Thomas, C., Jones, P. A., Rothwell, J., Chiang, C. Y., & Comfort, P. (2015). An investigation into the relationship between maximum isometric strength and vertical jump performance. *Journal of Strength and Conditioning Research, 29*(8), 2176–2185.
- Thomas, K., French, D., & Hayes, P. R. (2009). The Effect of Two Plyometric Training Techniques on Muscular Power and Agility in Youth Soccer Players. *Journal of Strength and Conditioning Research, 23*(1), 332–335.
- Thorborg, K., Petersen, J., Magnusson, S. P., & Hölmich, P. (2010). Clinical assessment of hip strength using a hand-held dynamometer is reliable. *Scandinavian Journal of Medicine and Science in Sports, 20*(3), 493–501. <https://doi.org/10.1111/j.1600-0838.2009.00958.x>
- Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2016). Tracking morning fatigue status across in-season training weeks in elite soccer players. *International Journal of Sports Physiology and Performance, 11*(7), 947–952. <https://doi.org/10.1123/ijsp.2015-0490>
- Towson, C., Cobley, S., Midgley, A. W., Garrett, A., Parkin, G., & Lovell, R. (2017). Relative age, maturation and physical biases on position allocation in elite-youth soccer. *International Journal of Sports Medicine, 38*(3), 201–209. <https://doi.org/10.1055/s-0042-119029>
- Turner, A. N., & Stewart, P. F. (2014). Strength and Conditioning for Soccer Players. *Strength and Conditioning Journal, 36*(4), 1–13.
- Turner, A., Walker, S., Stembridge, M., Coneyworth, P., Reed, G., Birdsey, L., ... Moody, J. (2011). A Testing Battery for the Assessment of Fitness in Soccer Players. *Strength and Conditioning Journal, 33*(5), 29–39. <https://doi.org/10.1519/SSC.0b013e31822fc80a>
- Unnithan, V., White, J., Georgiou, A., Iga, J., & Drust, B. (2012). Talent identification in youth soccer. *Journal of Sports Sciences, 30*(15), 1719–1726.
- Vaeyens, R., Güllich, A., Warr, C. R., & Philippaerts, R. (2009). Talent identification and promotion programmes of olympic athletes. *Journal of Sports Sciences, 27*(13), 1367–1380.

<https://doi.org/10.1080/02640410903110974>

- Vaeyens, R., Lenoir, M., Williams, A. M., & Philippaerts, R. M. (2008). Talent identification and development programmes in sport: current models and future directions. *Sports Medicine*, 38(9), 703–714. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/18712939>
- Vaeyens, R., Malina, R. M., Janssens, M., Van Renterghem, B., Bourgois, J., Vrijens, J., & Philippaerts, R. M. (2006). A multidisciplinary selection model for youth soccer: The Ghent Youth Soccer Project. *British Journal of Sports Medicine*, 40(11), 928–934.
- Vaeyens, R., Philippaerts, R. M., & Malina, R. M. (2005). The relative age effect in soccer: A match-related perspective. *Journal of Sports Sciences*, 23(7), 747–756.
<https://doi.org/10.1080/02640410400022052>
- Van Den Tillaar, R., & Marques, M. C. (2013). Reliability of seated and standing throwing velocity using differently weighted medicine balls. *Journal of Strength and Conditioning Research*, 27(5), 1234–1238. <https://doi.org/10.1519/JSC.0b013e3182654a09>
- Vandendriessche, J. B., Vaeyens, R., Vandorpe, B., Lenoir, M., Lefevre, J., & Philippaerts, R. M. (2012). Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years). *Journal of Sports Sciences*, 30(15), 1695–1703.
- Vandorpe, B., Vandendriessche, J., Vaeyens, R., Pion, J., Matthys, S., Lefevre, J., ... Lenoir, M. (2012). Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach. *Journal of Science and Medicine in Sport*, 15(3), 220–225.
<https://doi.org/10.1016/j.jsams.2011.09.006>
- Vescovi, J. D., Rupf, R., Brown, T. D., & Marques, M. C. (2011). Physical performance characteristics of high-level female soccer players 12-21 years of age. *Scandinavian Journal of Medicine & Science in Sports*, 21(5), 670–678. Retrieved from <http://doi.wiley.com/10.1111/j.1600-0838.2009.01081.x>
- Vigh-Larsen, J., Dalgas, U., & Andersen, T. B. (2018). Position-specific acceleration and deceleration profiles in elite youth and senior soccer players. *Journal of Strength and Conditioning Research*, 32(4), 1114–1122.
- Votteler, A., & Höner, O. (2014). The relative age effect in the German Football TID Programme: Biases in motor performance diagnostics and effects on single motor abilities and skills in groups of selected players. *European Journal of Sport Science*, 14(5), 433–442.

<https://doi.org/10.1080/17461391.2013.837510>

- Waldron, M., & Murphy, A. (2016). A Comparison of Physical Abilities and Match Performance Characteristics among Elite and Subelite Under-14 Soccer Players. *Pediatric Exercise Science*, 25(3), 423–434. <https://doi.org/10.1123/pes.25.3.423>
- Ward, P., & Williams, A. M. (2003). Perceptual and Cognitive Skill Development in Soccer: The Multidimensional Nature of Expert Performance. *Journal of Sport and Exercise Psychology*, 25(1), 93–111. <https://doi.org/10.1123/jsep.25.1.93>
- Whiteley, R., Jacobsen, P., Prior, S., Skazalski, C., Otten, R., & Johnson, A. (2012). Correlation of isokinetic and novel hand-held dynamometry measures of knee flexion and extension strength testing. *Journal of Science and Medicine in Sport*, 15(5), 444–450. <https://doi.org/10.1016/j.jsams.2012.01.003>
- Wik, E. H., McAuliffe, S., & Read, P. J. (2018). Examination of Physical Characteristics and Positional Differences in Professional Soccer Players in Qatar. *Sports*, 7(1), 9. <https://doi.org/10.3390/sports7010009>
- Williams, A. M., & Davids, K. (1998). Visual search strategy, selective attention, and expertise in soccer. *Research Quarterly for Exercise and Sport*, 69(2), 111–128. <https://doi.org/10.1080/02701367.1998.10607677>
- Williams, A. M., & Reilly, T. (2000). Talent identification and development in soccer. *Journal of Sports Sciences*, 18(9), 657–667.
- Wilson, R. S., James, R. S., David, G., Hermann, E., Morgan, O. J., Niehaus, A. C., ... Smith, M. D. (2016). Multivariate analyses of individual variation in soccer skill as a tool for talent identification and development: utilising evolutionary theory in sports science. *Journal of Sports Sciences*, 34(21), 2074–2086. <https://doi.org/10.1080/02640414.2016.1151544>
- Winter, E., Jones, A., Davison, R., Bromley, P., & Mercer, T. (2007). *Sport and Exercise Physiology Testing Guidelines: Volume I - Sport Testing: The British Association of Sport and Exercise Sciences*. Routledge.
- Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, 38(3), 285–288. <https://doi.org/10.1136/bjism.2002.002071>
- Wittich, A., Oliveri, M. B., Rotemberg, E., & Mautalen, C. (2001). Body composition of professional football (soccer) players determined by dual X-ray absorptiometry. *Journal of Clinical*

Densitometry, 4(1), 51–55. <https://doi.org/10.1385/JCD:4:1:51>

- Wong, P.-L., Chamari, K., Dellal, A., & Wisloff, U. (2009). Relationship Between Anthropometric and Physiological Characteristics in Youth Soccer Players. *Journal of Strength and Conditioning Research*, 23(4), 1204–1210.
- Woods, C. T., Joyce, C., & Robertson, S. (2016). What are talent scouts actually identifying? Investigating the physical and technical skill match activity profiles of drafted and non-drafted U18 Australian footballers. *Journal of Science and Medicine in Sport*, 19(5), 419–423. <https://doi.org/10.1016/j.jsams.2015.04.013>
- Wright, M. D., & Chesterton, P. (2018). Functional Movement Screen™ total score does not present a gestalt measure of movement quality in youth athletes. *Journal of Sports Sciences*, 00(00), 1–10. <https://doi.org/10.1080/02640414.2018.1559980>
- Wrigley, R. ., Drust, B., Stratton, G., Atkinson, G., & Gregson, W. (2014). Long-term Soccer-specific Training Enhances the Rate of Physical Development of Academy Soccer Players Independent of Maturation Status. *International Journal of Sports Medicine*, 35, 1090–1094. <https://doi.org/10.1055/s-0034-1375616>
- Yeadon, M. ., Kato, T., & Kerwin, D. . (1999). Measuring running speed using photocells. *Journal of Sports Sciences*, 17(3), 249–257.
- Yorkin, M., Spaccarotella, K., Martin-Biggers, J., Quick, V., & Byrd-Bredbenner, C. (2013). Accuracy and consistency of weights provided by home bathroom scales. *BMC Public Health*, 13(1), 1–5. <https://doi.org/10.1186/1471-2458-13-1194>
- Young, W. B., Dawson, B., & Henry, G. J. (2015). Agility and Change-of-Direction Speed are Independent Skills: Implications for Training for Agility in Invasion Sports. *International Journal of Sports Science & Coaching*, 10(1), 159–169. <https://doi.org/10.1260/1747-9541.10.1.159>
- Young, W. B., Farrow, D., Pyne, D., McGregor, W., & Handke, T. (2011). Validity and Reliability of Agility Tests in Junior Australian Football Players. *Journal of Strength and Conditioning Research*, 25(12), 3399–3403.
- Young, W. B., James, R., & Montgomery, I. (2002). Is muscle power related to running speed with change direction? *Journal of Sports Medicine and Physical Fitness*, 42(3), 282–288.
- Young, W., Dawson, B., & Henry, G. (2015). Agility and Change-of-Direction Speed are Independent Skills: Implications for Agility in Invasion Sports. *International Journal of Sports Science & Coaching*, 10(1), 159–169. <https://doi.org/10.1260/1747-9541.9.5.1153>

Young, W., & Farrow, D. (2013). The Importance of a Sport-Specific Stimulus for Training Agility. *Strength & Conditioning Journal*, 35(2), 39–43.

Zibung, M., & Conzelmann, A. (2013). The role of specialisation in the promotion of young football talents: A person-oriented study. *European Journal of Sport Science*, 13(5), 452–460.
<https://doi.org/10.1080/17461391.2012.749947>