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Quantifying the Physical, Technical, and Tactical Qualities Discriminant of Development Level in the Queensland Rugby League Talent Pathway

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BSpExSc (Hons)

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Doctor of Philosophy

COLLEGE OF HEALTHCARE SCIENCES

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July 2020

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The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007). The proposed research methodology received human research ethics approval from the James Cook University Human Research Ethics Committee (approval numbers H6768, H7183, H7685).

21 July 2020

Leesa Grier　　　　　　　　　　　　　　　　　　　　　　Date

STATEMENT OF CONTRIBUTION OF OTHERS

Nature of Assistance	Contribution	Names, Titles and Affiliations of Co-Contributors
Intellectual support	Proposal writing Data Analysis Statistical support	Carl Woods, Anthony Leicht, Wade Sinclair Miguel Gomez statistical support – Chapter 5
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PUBLICATIONS CONTRIBUTING TO THIS THESIS

Pearce, L. A., Sinclair, W. H., Leicht, A. S., & Woods, C. T. (2018). Physical, anthropometric, and athletic movement qualities discriminate development level in a rugby league talent pathway. *The Journal of Strength & Conditioning Research*, *32*(11), 3169-3176.

Pearce, L. A., Sinclair, W. H., Leicht, A. S., & Woods, C. T. (2019). Passing and tackling qualities discriminate developmental level in a rugby league talent pathway. *International Journal of Performance Analysis in Sport*, *19*(6), 985-998.

PRESENTATIONS CONTRIBUTING TO THIS THESIS

Pearce, L. A. Passing and tackling qualities discriminate developmental level in a rugby league talent pathway (June 4-7, 2019). *9th World Congress of Science and Football,* Melbourne, Victoria.

THESIS OVERVIEW

Rugby league (RL) is a popular team invasion sport primarily played in Australia, New Zealand, and the United Kingdom. With its popularity continuing to grow, there is an underlying importance to provide rich learning and development environments for youngsters interested in pursuing a career at the elite level (i.e., within the National Rugby League). The intentions of such learning environments should be to accelerate skill development through the provision of evidence-based training activities and organisational structures. To aid this process, this thesis examined the performance qualities of talent identified juniors at different stages of the Queensland (Qld) RL talent pathway. Specifically, by comparing the physical, technical, and tactical performance qualities of players at the Under 18 (U18), Under 20 (U20) and State League (SL) levels, this thesis was able to identify key practical performance differences to inform training designs and proposed organisational (re)structures within the Qld RL talent pathway.

This thesis consists of seven Chapters, with Chapters 1 and 2 providing a brief introduction and narrative review surrounding talent and its subsequent development in sport, with a specific focus on talent development in RL. Chapter 3 is the first in a series of research studies and examines the physical performances qualities of players at the U18, U20 and SL levels in the Qld RL talent pathway. The main findings of this chapter included the similarities in the performance qualities between the U18 and U20 levels, and the large difference between these combined levels and the SL. Of note were the SL participants being heavier, producing a greater peak and average power output, and demonstrating superior athletic movement competencies relative to the U18 and U20 levels.

Similar themes were evident in Chapter 4 with the U18 and U20 cohorts showing a large deficit of technical skill for passing and tackling relative to their SL peers. Interestingly, for passing distances greater than 4m, it was noted that all development levels showed decrements in passing accuracy for right-to-left passing, including an increased number of forward passes. Additionally, tackle type preferences discriminated U18 and U20 levels from the SL with the SL being superior in all tackle assessments.

Having examined the physical (Chapter 3) and technical (Chapter 4) performance qualities of players within the Qld RL talent pathway, Chapter 5 examined the tactical qualities of players observed during an attack-play task. The main findings of this study demonstrated differences in both starting position and evasive manoeuvres used between the SL participants and the U18 and U20 levels. Notably, the SL participants performed a significantly greater number of combined evasive manoeuvres and appeared to intentionally position themselves at task initiation, likely to draw a defender toward them, when compared to both the U18 and U20 levels.

Chapters 6 and 7 conclude the thesis, summarise its findings, discuss its practical implications, and highlight areas for future research. Some of the practical implications stemming from this thesis include: 1) an organisational restructure to combine the U18 and U20 levels, thereby creating a 'Juniors Competition' in an effort to optimise both financial and time resources, and 2) informing the design of training programs intended to assist with the skill development of juniors within the Qld RL talent pathway.

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LIST OF ABBREVIATIONS

AAA	Athletic Ability Assessment
AF	Australian Football
AUC	Area under the curve
A1	Attack player 1
A2	Attack player 2
A3	Attack player 3
cm	Centimeter
DL	Defender left
DMGT	Differentiated Model of Giftedness to Talent
DR	Defender right
ESL	European Super League
kg	Kilogram
m	Metre
MANOVA	Multivariate analysis of variance
NRL	National Rugby League
NSW	New South Wales
OH	Over-head
P	Passer
Qld	Queensland
QRL	Queensland Rugby League
RHIE	Repeated high intensity effort
RL	Rugby league
RLTP	Rugby league talent pathway
ROC	Receiver operating characteristics

s	Second
SL	State League
SLRDL	Single leg Romanian deadlift
SPSS	Statistical Package for Social Science
UK	United Kingdom
U13	Under 13 years
U14	Under 14 years
U16	Under 16 years
U18	Under 18 years
U20	Under 20 years
VO_{2max}	Maximal volume of oxygen consumed during exercise

Chapter 1 Introduction

1.1 A Brief Background to Rugby League

Rugby league (RL) originated as a break-away competition to rugby union in the United Kingdom (UK) in 1895 (Fagan, 2011). In these early days, it was typically referred to as the Northern Rugby Football Union and was based in Huddersfield, UK (Fagan, 2011). The Northern Rugby Football Union competition later evolved into the Rugby Football League, with international competitions emerging in Australia and New Zealand in 1907 (Fagan, 2011). The inaugural New South Wales (NSW) Rugby Football League season was played in Australia in 1908 and consisted of teams within the NSW region (Trueman, 2017). The interest in RL instigated the inaugural Brisbane RL Premiership in 1909 (Fagan, 2011) and by the 1920's, RL participation rates across Queensland (Qld) and NSW rivalled that of other Australian football codes, such as rugby union and Australian football (AF) (Trueman, 2017).

The modern game is contested between two teams of 13 players, with each team being permitted six consecutive attempts to carry the ball forward (gaining territory toward the goal line) to score a 'try'. If unable to score a try within the six-tackle limit, the ball is handed to the opposition and the cycle is repeated throughout the course of approximately 80 minutes of game play. The premier Australasian competition, referred to as the National Rugby League (NRL), consists of 16 teams from NSW, Qld, the Australian Capital Territory, Victoria and New Zealand, yielding a television and spectator audience of greater than 108 million each year (Masters, 2009). Given the popularity of RL, participation programs such as the Qld and NSW RL elite pathways have been established to nurture prospective talent (League Unlimited, 2018). These important talent development pathways aim to provide governing RL bodies, both locally (state-based organisations) and nationally, with an instrument to develop players capable of performing in the elite senior competition (i.e., within the NRL). Whilst existing in both Qld and NSW, this thesis explicitly focuses on the Qld RL talent development pathway.

1.2 Talent Development Pathway in Queensland Rugby League

In Qld, the talent development pathway formally commences at the Under 18 (U18) level, with International rules observed from the age of 13 years (Rugby League competition in Australia is modified for players 6 to 12 years). Talented juniors may be identified from secondary school, Under 16 (U16) and Under 14 years (U14) competitions (Figure 1), and invited to join a RL club that is registered to compete in the state-based competition. These RL clubs have a squad of players that compete in each of the three developmental levels: U18, Under 20 years (U20) and State League (SL; open age). However, exceptional junior players under the age of 20 years of age may be registered to SL squads forgoing the traditional pathway.

Fundamentally, the goal of this formalised talent development pathway is to expedite the RL skills of players for an effective junior-to-senior transition. Accordingly, understanding talent and its subsequent five stages, including 'development' would be crucial for coaches within these clubs so they may scaffold practices undertaken within the Qld RL talent pathway (RLTP) (Williams, Ford, & Drust, 2020; Williams & Reilly, 2000).

1.3 The Five Stages of Talent in Sport

It is common practice for national sporting bodies and federations to explore methods of accelerating the development of skill for the attainment of expertise (Abernethy, Baker, & Côté, 2005). To support this process, many organisations around the world such as Aspire in Qatar, the English Institute of Sport, and the Australian Institute of Sport (Durand-Bush & Salmela, 2010), underpin practice using the five stages of talent first described by Williams and Reilly (2000). These stages are detection, identification, development, selection, and confirmation and are displayed in Figure 2.

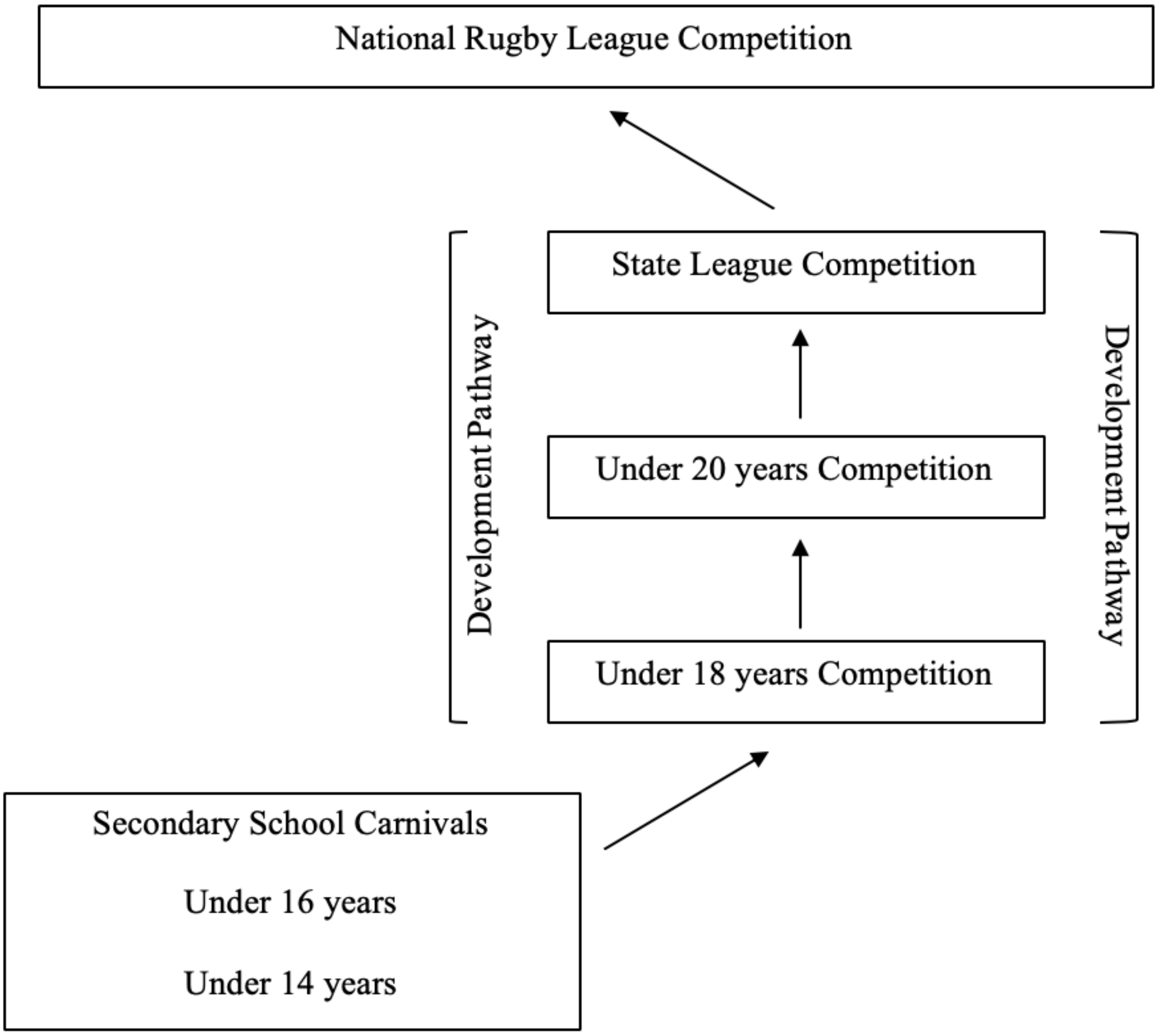

Figure 1. A schematic of the current Rugby League talent pathway in Queensland.

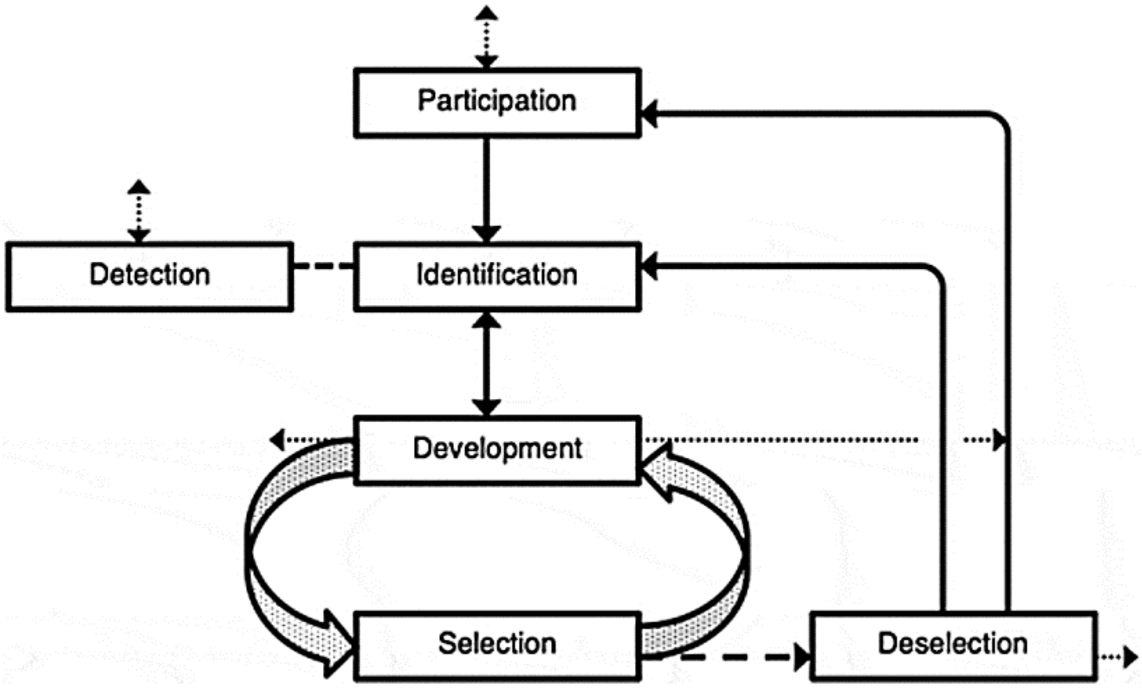

Figure 2. A diagrammatic representation of the five stages underpinning the theoretical understanding of talent as adapted from Williams et al. (2020) (Permission granted from publisher).

1.3.1 Detection

Talent detection can be defined as the discovery of an individual who demonstrates a superior motor ability that could enable the successful participation in a pre-determined sport or sporting activity (Williams et al., 2020; Williams & Reilly, 2000). A talent 'detected' individual is one not yet participating in a sport but is deemed to have potential to progress competitively within talent development programs for a sport. The premise of talent detection programs, such as the Talent Search Program used by the Australian Institute of Sport, is to assess large groups of school aged children and 'detect' those who possess 'gifts' that align with sports or sporting activities (Australian Rugby League Commission, 2015). The efficacy of detection programs are perhaps greater in sports where success is primarily attributed to the mastery of one component (i.e., having an inherently large VO_{2max} may encourage the detection of an individual for track cycling) (Williams et al., 2020; Williams & Reilly, 2000). Sports with shallow participation pools, like winter Olympic sports in Australia, also benefit from talent detection programs via the promotion of participation (Pearson, Naughton, & Torode, 2006).

1.3.2 Identification

Talent identification can be understood as the recognition of performance potential within a specific sport from a relatively homogenous population (Vaeyens, Lenoir, Williams, & Philippaerts, 2008). The individual is already participating in the sport and demonstrates a high level of coach-ability and sensitivity to training, which increases potential for advanced skill development (Vaeyens et al., 2008). In recent years, sport scientists have progressed toward a multidimensional approach to talent identification in team sports (Williams et al., 2020), suggesting that key predictor variables for expert performance are likely demonstrated across the physical, technical, and tactical qualities of game play (Launder, 2001). Identifying the physical, technical, and tactical performance qualities discriminant of talent will likely provide coaching staff with the knowledge of expected performance 'benchmarks' (e.g. attributes descriptive of talented performances), thereby exposing performance differences between talent identified and non-talent identified individuals. These benchmarks may subsequently be used as reference values to inform the design of training programs intended to accelerate the skill development of talented juniors (Woods, Bruce, Veale, & Robertson, 2016a).

1.3.3 Development

The next stage of 'talent' is development (Figure 2), and is defined as the provision of an opportunistic learning environment that aims to streamline the attainment of expertise (Vaeyens et al., 2008; Williams & Reilly, 2000). The development stage represents chronic and strategic implementation of training interventions designed to accelerate the skill development of junior athletes as they progress through developmental levels toward senior competitions (Vaeyens et al., 2008; Williams & Reilly, 2000). Although the primary goal of talent development is to produce the expert performer (Vaeyens et al., 2008; Williams & Reilly, 2000), it should concurrently function to increase long-term sporting participation and involvement (Vaeyens et al., 2008), thereby making it a crucial stage of the broader 'talent' process.

With a specific focus on team sports, talent development programs should ultimately function to accelerate the development of the performance qualities needed during competition (Williams et al., 2020; Williams & Reilly, 2000). It may be a unique combination of qualities specific to the sport (e.g. physical, technical, and tactical), which discriminate talented individuals from their peers within the development pathway (Gabbett, Jenkins, & Abernethy, 2011a; Launder, 2001; Reilly, Williams, Nevill, & Franks, 2000). For example, a combination of sport-specific physical and technical skills were shown to discriminate developmental level in AF (Gaudion, Doma, Banyard, Sinclair, & Woods, 2017). Further, the combination of performance qualities discriminative of developmental level in soccer was reported to vary across the junior-to-senior development pathway, suggesting practitioners should consider the dynamic and multidimensional nature of talent development (Vaeyens et al., 2006). This is important to note, as previous research has demonstrated that a 'one size fits all' model of development does not work within a talent pathway, and that practitioners need a firm appreciation of the developmental 'gaps' between participants at different levels to help inform targeted training designs (Côté & Vierimaa, 2014; Launder & Piltz, 2006; Williams et al., 2020). Accordingly, it is this stage of talent that this thesis explicitly examines, as to date, there has been little empirical research detailing the physical, technical, and tactical qualities that discriminate the different levels within a RL talent development pathway (see section 1.4 of this chapter).

1.3.4 Selection

Talent selection is a process practitioners undertake when choosing (or selecting) the most appropriate athlete(s) to compete in a specific sporting activity (Williams et al., 2020; Williams & Reilly, 2000). An example of this may be a coach selecting four swimmers to compete in an Olympic relay team from a broader talent pool of swimmers. The selection process for elite senior sporting squads is merited, as it encourages in-group competition and motivation to succeed (Williams et al., 2020; Williams & Reilly, 2000). However, it can have opposite effects within junior sporting environments, as individuals regularly not selected for participation may become discouraged, de-motivated and even cease participation (Tranckle & Cushion, 2006).

1.3.5 Confirmation

Confirmation is the final stage of sporting talent, and is the stage where practitioners retrospectively analyse the preceding four stages that were implemented (Williams et al., 2020; Williams & Reilly, 2000). For example, it encourages practitioners (and sporting organisations) to actively review whether they detected, identified, developed, and selected the 'right' individuals. Interestingly, this stage is often missed both in practice and research, perhaps given its longitudinal and cumbersome nature (Williams et al., 2020; Williams & Reilly, 2000). Nonetheless, it is crucial when determining the broader efficacy of the four stages of detection, identification, development, and selection (Williams et al., 2020; Williams & Reilly, 2000).

1.4 Performance Qualities of Rugby League Game Play

Successful participation in RL requires a range of performance qualities that can be broadly classified into physical, technical, and tactical components (Johnston, Gabbett, & Jenkins, 2014). Prior research has examined each of these components distinctly, identifying a range of performance differences between players across both junior and senior levels (Austin, Gabbett,

& Jenkins, 2011; Geeson-Brown, Jones, Till, Chantler, & Deighton, 2020; Glassbrook, Doyle, Alderson, & Fuller, 2019; Till, Cobley, O'Hara, Chapman, & Cooke, 2013; Till, Scantlebury, & Jones, 2017). Of particular relevance to this thesis, differences in physical qualities within the UK RLTP have been examined, with results providing knowledge for practitioners to narrow the gaps of performance between development level (Ireton, Till, Weaving, & Jones, 2017; Till, Jones, Darrall-Jones, Emmonds, & Cooke, 2015b; Till et al., 2014a; Till et al., 2014b). However, such rich insight into the performance gaps between developmental levels within an Australian RLTP (NSW or Qld) is yet to be explored, offering an enticing area that this thesis will empirically inform.

The importance of physical, technical, and tactical performance qualities for successful game play is clearly not just confined to RL. Specifically, Launder (2001) proposed a theoretical model (reviewed in greater detail in Chapter 2) that advocates a range of skills and abilities needed by team sport athletes to exhibit a 'skilled' performance (Figure 3). Applied to RL, the physical performance qualities needed would likely include speed, agility, power, and movement competency; the technical qualities would likely include passing and tackling skill; and the tactical qualities would likely include decision-making skill (Gabbett, 2014; Ireton et al., 2017; Till et al., 2015a; Till et al., 2017). Accordingly, linking the prior mentioned gap between development levels to Launder's (2001) model, this thesis aims to compare the physical, technical, and tactical performance qualities of RL players across a talent pathway within Australia. The practical implications of this research will provide practitioners working within the Qld RLTP with detailed insights into the performance gaps between key developmental stages. More specifically, this knowledge may underwrite relevant training practices and organisational structures currently utilised within the current Qld RLTP, contributing to a meaningful and effective talent pathway for participants.

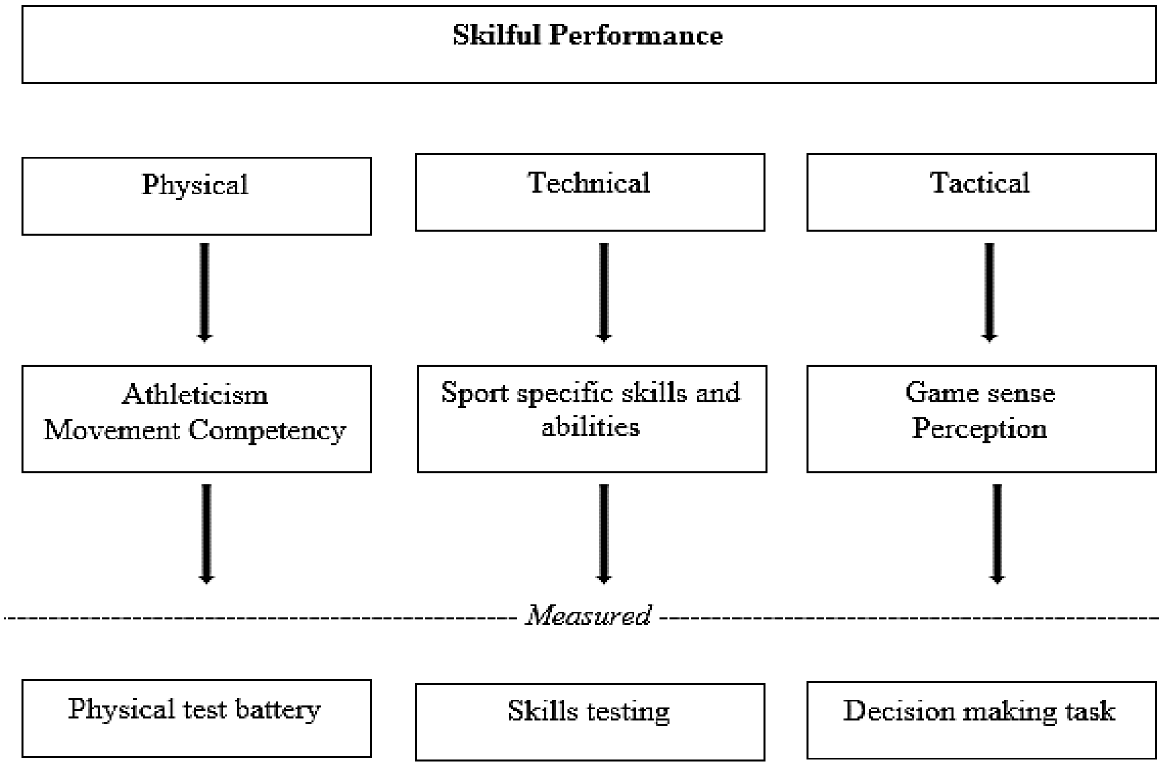

Figure 3. The model of a skilful player as adapted from Launder (2001).

1.5 Thesis Overview

Given the physical, technical, and tactical requirements of RL, this thesis will use Launder's (2001) model to examine performance qualities of participants at different stages of the Qld RLTP. It consists of seven chapters, the first of which has briefly introduced RL in addition to key themes that will be explored throughout the remainder of the thesis. Chapter 2 offers a narrative review of the literature as a theoretical and practical construct. Specifically, talent development models will be reviewed, followed by the integration of such models in some team sports. Secondly, the limitations associated with current talent development practices in RL will be examined, providing a basis for the ensuing research studies. Chapters 3, 4, and 5 will document studies that address a research question detailed within this thesis. Chapter 6 will provide a thesis summary and conclusion with future directions for research, while Chapter 7 will discuss the practical implications of this thesis and its findings for the Qld RLTP.

Chapter 2 Review of the Literature

This chapter presents a narrative review that critiques the relevant literature to frame the proceeding research chapters within this thesis (Chapter 3-5). It is split into two sections; the first will discuss the multidimensionality (i.e., physical, technical, and tactical) of team sports' performance using Launder's (2001) Model of a Skilful Player as a theoretical basis for explanation. It will then discuss 'talent', its development, and its application to team sports. The second section of this review has a greater focus on the physical, technical, and tactical requisites of RL game play and existing talent development practices within the game, concurrently emphasising the gaps in which this thesis will endeavor to fill.

2.1 A Theoretical Model for Appreciating the Multidimensionality in Team Sports Performance

As briefly discussed in Chapter 1, the Model of a Skilful Player, proposed by Launder (2001), offers a theoretical framework that advocates the multidimensional requirements of team sports performance. The framework has evolved to team sports from Launders contribution to pedagogy and physical education, in which he introduced the 'play practice' approach to influence children's play as an opportunity to learn a range of sporting skills (Stolz & Pill, 2014).

The first layer of this framework broadly classifies a 'skilful performance' in team sports as a result of physical, technical, and tactical qualities (Figure 3). The next layer offers insight with regards to the fundamental skills / abilities that may be observed within each dimension. For example, physical skills / abilities such as athleticism, movement competency, aerobic and anaerobic capacity, strength, and power may all underpin a 'skilful performance' in team sport (Launder, 2001). Technical skills / abilities broadly encapsulate specific requirements of the team sport being analysed, such as kicking in soccer and AF, batting in cricket and baseball, or passing and shooting in basketball and netball (Janelle & Hillman, 2003). Tactical skills / abilities are inclusive of qualities such as decision-making, and 'game sense' (defined through a situational awareness and environmental attunement) (Gréhaigne, Godbout, & Bouthier, 2001). The last layer of the Model of Skilful Player is the measurement or quantification of these skills / abilities (Figure 3). Accordingly, understanding the physical, technical, and tactical requirements of game play, specific to the sport of interest will inform relevant assessment tasks used to quantify the skill / ability of the athlete (Launder, 2001).

Pertinent to the scope and intentions of this thesis, it is the subsequent measurement of the physical, technical, and tactical skills / abilities that can be used to inform a range of practices within sport, such as the prescription of training activities to assist with talent development (Gabbett, Kelly, Ralph, & Driscoll, 2009b; Ireton et al., 2017; Johnston & Morrison, 2016; Speranza et al., 2017). For example, this theoretical framework has underpinned talent identification and development research in team sports, such as AF (Woods, Raynor, Bruce, & McDonald, 2015b), with such research offering a directive for designing and implementing evidence-based identification and development programs in the game (Gaudion et al., 2017). The model developed by Launder (2001), therefore, offers an appropriate theoretical framework for the research chapters to follow within this thesis (Chapters 3-5). However, prior to discussing how such a theoretical framework may support similar research in RL, the following sections will discuss the theoretical underpinnings of 'talent' and its subsequent development in sport.

2.2 The Differentiating Model of Giftedness and Talent: A Theoretical Basis for Talent Development

According to the Differentiating Model of Giftedness and Talent (DMGT; Figure 4), 'talent' can be defined as a performance that places an individual in the top 10% relative to age-matched peers (Gagné, 2000), and is typically examined in systematically developed fields such as academia, the arts, business, and sport. Comparatively, a 'gift' can be defined as natural ability that places an individual in the top 10% relative to their age-matched peers (Gagné, 2000), and is typically examined in the intellectual, creative, social, perceptual or sensorimotor domains (Figure 4). As demonstrated in the DMGT (Figure 4), a gifted individual will not necessarily develop into a talented individual, as the talent development process is often complex, non-linear, and influenced (either negatively or positively) by three catalysts; intrapersonal factors, environmental constituents, and chance (Gagné, 2000). Briefly, intrapersonal factors include personality, the development of self-regulation, and intrinsic motivation (Gagné, 2000). Environmental catalysts are inclusive of sociocultural influences, residential location, milieu, and interpersonal relationships (Gagné, 2000). Lastly, the recognition of chance being a mediator in the development of talent is unique to this model, and perhaps pays tribute to the colloquialism of 'being in the right place at the right time'.

Despite being initially proposed in the educational domain, the DMGT provides a comprehensive theoretical basis for situating talent development models in the sporting domain for two main reasons. Firstly, it addresses the dynamicity of talent development in sport through the acknowledgement of catalysts. For example, the components of the DMGT highlight the non-linear nature in which a gift may develop into a talent through the various dynamic interactions of environmental and interpersonal catalysts, in addition to chance. Secondly, it echoes the multidimensionality of team sports by highlighting that talent can emerge in a range of competency fields (Tranckle & Cushion, 2006; Vaeyens et al., 2008). Specifically, the appreciation of giftedness arising from four main categories within the DMGT (intellectual, creative, socioaffective and sensorimotor) links the perception that sporting expertise can arise from domains other than the sensorimotor. However, the development of performance qualities may not become fully apparent until the initiation of targeted developmental interventions specific to the sport of choice (Güllich & Emrich, 2006). Accordingly, it would be reasonable to extend these theoretical propositions of talent development beyond its emergence from 'giftedness' by highlighting how talent in sport may be developed.

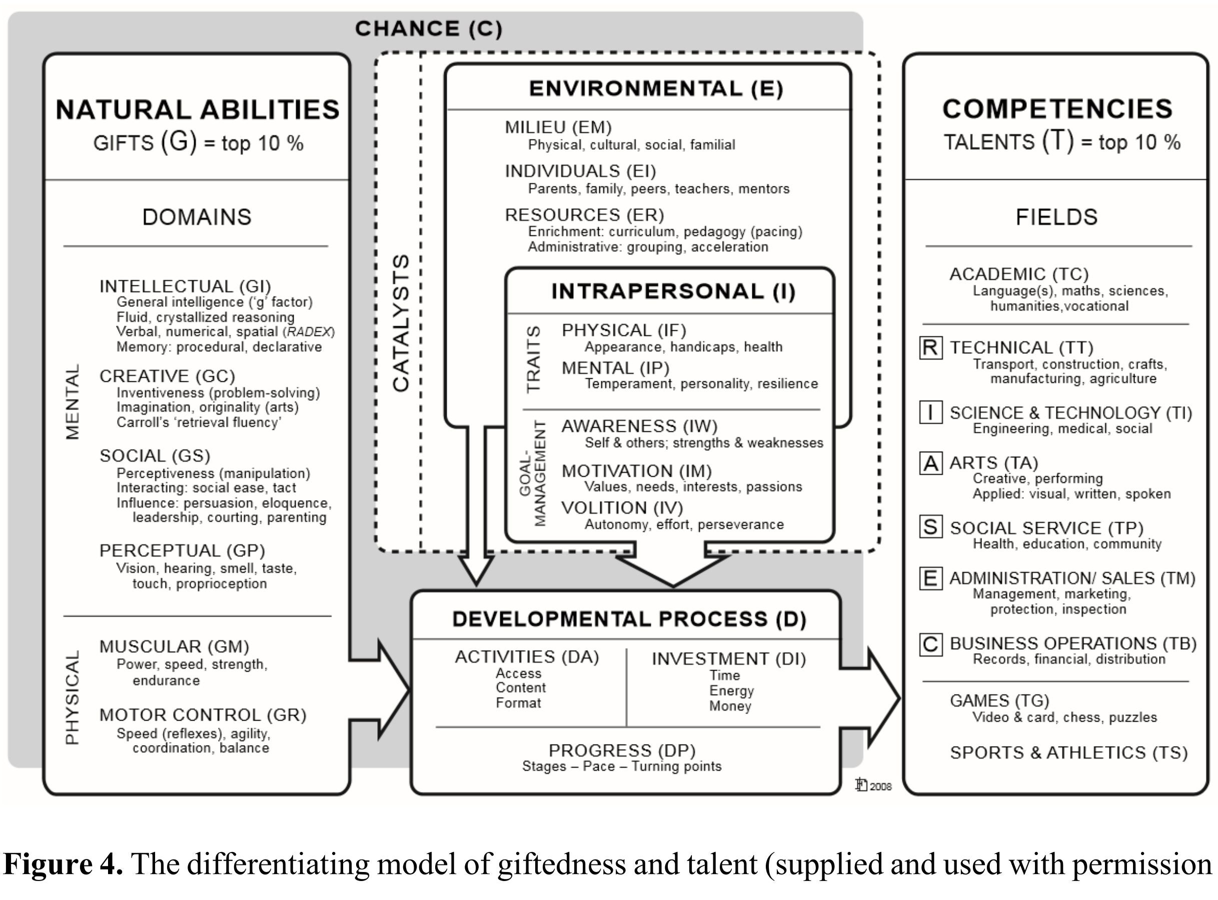

Figure 4. The differentiating model of giftedness and talent (supplied and used with permission from author, Françoys Gagné).

2.3 Talent Development Models in Sport

The examination of the gifted-to-talented development process in sport has paved the way for the establishment of talent development practices in sporting academies around the world such as La Masia in Barcelona, Aspire in Qatar, and the Australian Institute of Sport. These and many similar elite sporting organisations are likely to have examined the efficacy of theoretical development models such as the Deliberate Practice Theory (Ericsson, Krampe, & Tesch-Romer, 1993) and the Developmental Model of Sports Participation (Côté, 1999) to inform the design of learning environments (Figure 5). Discussed in greater detail below, the Deliberate Practice Theory proposes that sporting expertise is the consequence of early specialisation, typically around six years of age, in which the individual invests 10,000 hours or ten years of deliberate practice prior to the attainment of expertise (Ericsson et al., 1993). In contrast, the Developmental Model of Sports Participation advocates diversity in sporting activity early in development, progressively specialising toward the later years of adolescence (Côté, 1999). Importantly, it is this sporting diversity early in life that creates conditions conducive for expertise later in life (Côté, 1999). Despite these fundamental differences, the objective of each model is to offer a conceptual explanation of talent and expertise development in sport.

2.3.1 Deliberate Practice Theory

The Deliberate Practice Theory proposes that expertise development is proportionate to the number of hours invested in deliberate practice (Ericsson et al., 1993). These theoretical propositions define deliberate practice as a highly structured activity designed only to improve performance, and as such, it may not be inherently enjoyable for the participant (Chase & Simon, 1973; Ericsson et al., 1993). Despite the potential challenges of deliberate practice, this theory has been examined in many domains, such as music and academia (Chase & Simon, 1973; Ericsson et al., 1993). For example, the retrospective examination of expert violinists demonstrated that they had invested greater than ten years of deliberate practice prior to gaining expert status relative to non-expert violinists (Ericsson et al., 1993). Chess masters were also shown to have invested greater than ten years of deliberate practice prior to their mastery in comparison to their less masterful counterparts (Chase & Simon, 1973).

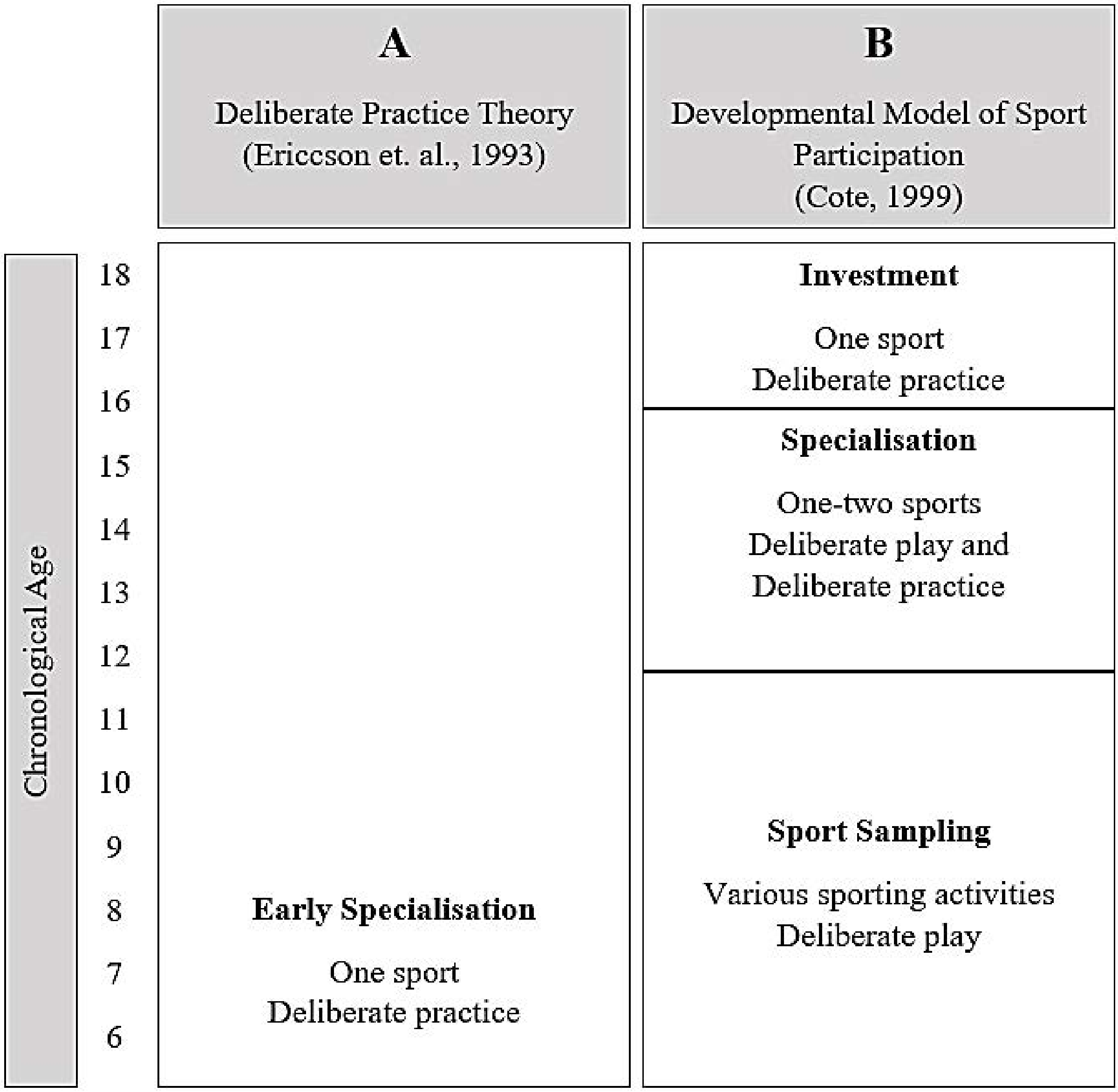

Figure 5. Talent development models in sport – **A)** Deliberate practice theory, and **B)** Developmental model of sport participation

Such a deliberate approach to talent development may assist sports that require early specialisation such as gymnastics, ballet, swimming and figure skating, where appearance at the highest competition level is at relatively young ages (Atiković, Kalinski, & Čuk, 2017; Ekegren, Quested, & Brodrick, 2014; Lang, 2010). For example, rhythmic gymnasts' anthropometric characteristics (such as lean body composition and short standing height), alongside explosive strength and athleticism could be advantageous for performance (Arriaza et al., 2016). Equally, ballet dancers may be elite performers at mid to late adolescence, executing powerful movements from lithe body compositions to vie for apprenticeships into corps de ballet within professional dance companies (Ekegren et al., 2014). Swimming and figure skating may also introduce deliberate practice from childhood, with the sole focus throughout this development period being to undertake targeted and purposeful training with the intent of winning and / or attaining expertise (Lang, 2010). However, discussed in more detail below, early specialisation and deliberate practice in sport attracts some notable shortcomings, such as loss of enjoyment, early burnout and / or injury (Mostafavifar, Best, & Myer, 2013). Accordingly, talent development models that advocate a greater and more diverse sporting involvement are being looked upon more favorably in the sporting domain (Côté, 2014; Durand-Bush & Salmela, 2010; Gagné, 2000; Williams et al., 2020).

2.3.2 The Developmental Model of Sports Participation

In contrast to the Deliberate Practice Theory, the Developmental Model of Sports Participation proposes that expertise development is supported through diverse and enjoyable sporting involvement and physical activity during childhood and early adolescence (Côté, 1999). There are three stages detailed within the Developmental Model of Sports Participation, which progressively move from deliberate play early in life to deliberate practice later in life. The first stage of the model, the sampling years (~ six to 12 years of age), is categorised through deliberate play activities experienced through a variety of sport and physical activity involvements (Figure 5B). Through this deliberate play within the sampling years, children are afforded the freedom to explore their own sporting involvements, and in doing so, learn a range of perceptual and motor skills vital for sporting involvement later in life (Côté, Lidor, & Hackfort, 2009). Importantly, this advantageous nature of sport sampling has been shown to be a common trait within expert performers in a range of sports (Côté et al., 2009; DiStefano et al., 2018; Goodway & Robinson, 2015). For example, in a retrospective study of elite and sub-elite ice hockey players, Soberlak and Côté (2003) noted that the elite players had engaged in up to six different sports throughout childhood in contrast to their sub-elite counterparts. The authors concluded that in addition to the development of a range of motor and perceptual skills, the enjoyment experienced from participating in a wide variety of sporting activities likely assisted with the development of intrinsic motivation and self-regulation within the elite ice hockey players (Soberlak & Cote, 2003).

The second stage of the Developmental Model of Sports Participation is the specialising years (Figure 5B). Notable around the onset of puberty (~ 13 years of age), the specialising years see an adolescent narrow their focus toward the refinement of the specific skills needed to attain expertise in one or two sports (e.g. cricket and soccer) (Côté, 1999, 2014). This stage incorporates deliberate play and progresses individuals toward deliberate practice by introducing a more structured training regime for the purpose of performance improvement (Côté, 1999, 2014). Importantly, the individual’s choice to focus on one or two sports is their own, being primarily driven by positive experiences within the chosen sport(s), such as having a positive and supportive coaches, teammates and / or successful performances (MacPhail & Kirk, 2006).

The final stage, the investment years, is characterised by an increased focus on strategic and technical skill development within one specific sport and typically initiates around the age of 16 years (Côté, 2014). It is in this stage that deliberate practice is usually integrated, with seasonal sports becoming year-long sports given the initiation of an extensive preseason training phrase (Windt, Gabbett, Ferris, & Khan, 2017). Given the chronological age of juniors when they reach this stage, they are likely to have started developing the cognitive, social, and emotional maturity necessary for deliberate practice (Côté & Vierimaa, 2014). Further, the biological growth during late adolescence (e.g. anatomical, hormonal and musculoskeletal), becomes less dynamic and chaotic in this stage with physiological performances likely to be the result of training adaptation rather than inter-athlete biological variations (Balyi & Hamilton, 2004; Côté et al., 2009; Desmangles, Lappe, Lipaczewski, & Haynatzki, 2006). Of direct importance to the research chapters within this thesis, it is around this stage (typified within an U18 age group) that 'formalised' talent development pathways initiate in team sports (Gaudion et al., 2017).

There is a growing amount of research in sports science that supports the sporting diversity foundations of the Development Model of Sport Participation (Berry, Abernathy, & Côté, 2008; Bruce, Farrow, & Raynor, 2012). For example, Bruce et al. (2012) retrospectively examined the developmental histories of elite netball players, noting that they invested more time in the participation of invasion team sports activities outside of netball when compared to their sub-elite counterparts within the sampling years. Similarly, Berry et al. (2008) noted that expert AF decision-makers invested greater amounts of time in invasion activities relative to peers. These studies suggest that sporting diversity, particularly early in the developmental pathway, may lead to a positive transfer of learning (Abernethy et al., 2005; Berry et al., 2008; Bruce et al., 2012). In support of this notion, Abernethy et al. (2005) noted that elite athletes from a variety of team invasion sports demonstrated a positive transfer of tactical skill to a variety of ‘unfamiliar’ team sports. Cumulatively, these results indicate that participation in diverse sporting activities during early developmental stages are likely to complement the development of more sport specific skills later in life. Practitioners responsible for developing athletes, particularly early in development (<15 years of age), should, therefore, consider the propositions of the Developmental Model of Sports Participation when designing learning environments for juniors by promoting rich, diverse, and inherently enjoyable sporting involvements.

2.4 Talent Development Models in Team Sport: Some Brief Applied Examples

Team sports such as cricket, netball, AF and soccer often use talent development models that align with the theoretical underpinnings of the Developmental Model of Sports Participation to guide training programs and the structure of developmental pathways and / or academies (Ford et al., 2011; Fransen et al., 2017; Phillips, Davids, Renshaw, & Portus, 2010). Such developmental pathways have tended to adopt a more ‘athlete-centered’ approach (Phillips et al., 2010), with practice and training activities undertaken being informed by the developmental gaps between levels (i.e., U18 and U20), rather than based around the needs of athletes competing just at the elite competition level (Byron & Chepyator-Thomson, 2015; Cripps, Joyce, Woods, & Hopper, 2017). More directly, this has guided the development of talent through the identification of physical, technical, and tactical performance gaps between developmental levels (i.e., U16 and U18). Such research could be applied to RL, thereby guiding talent development within the game, particularly in Australia.

2.4.1 Australian Football

Similar to RL, AF is a multidimensional team invasion sport, requiring players to blend a range of physical, technical, and tactical qualities to exhibit a skilful performance (Coutts, Quinn, Hocking, Castagna, & Rampinini, 2010; Edgecomb & Norton, 2006). For example, throughout game play, players engage in a range of tactical and technical tasks in both offence (i.e., determining who to kick or handball the ball to) and defence (i.e., leaving an opponent to affect a contest by 'spoiling' the ball), interspersed with repeated efforts of high intensity running and tackling (Coutts et al., 2010; Edgecomb & Norton, 2006).

With a specific focus on talent identification and development, research has compared the physical profiles of players at different stages of the talent pathway (Gray & Jenkins, 2010; Kempton, Sullivan, Bilsborough, Cordy, & Coutts, 2015). Specifically, anthropometric and physical measures such as standing height, body mass, aerobic fitness and lower body power were reported to discriminate talent identified U18 AF players from their peers (Woods, Raynor, Bruce, McDonald, & Collier, 2015a). Further, Gaudion et al. (2017) demonstrated such physical qualities also discriminated identified U18 players from their U16 level counterparts, suggesting the practitioners within the talent pathway should design training activities at the U16 that target these noted performance gaps to enhance the development of talent. However, appreciating Launder's (2001) model discussed earlier, physical performance qualities are only one element of a skilful performance in team sports. Consequently, AF talent development research has also explored the technical and tactical performance qualities of players at different development levels (Ball, 2008; Robertson, Back, & Bartlett, 2016). For example, the technical skills most discriminant of talent at the U18 level in AF have been shown to include kicking (both speed of ball flight and accuracy toward target) and handballing (accuracy toward target) (Woods et al., 2015b), results similar to those found at the U16 level (Cripps et al., 2017).

Collectively, the emphasis here is that these AF studies have afforded practitioners within the talent pathway with the knowledge to address the physical, technical, and tactical ‘gaps’ between developmental levels to bolster athlete transition and development in the game (Woods, Raynor, Bruce, & McDonald, 2016d; Woods et al., 2015a; Woods et al., 2015b). In light of this, the ‘formalised’ talent development pathway within AF now routinely conducts physical, technical, and tactical testing to guide both the identification and subsequent development of talented juniors (Woods, Raynor, Bruce, McDonald, & Robertson, 2016e). Pertinent to the scope of this thesis, to date, such systematic testing to guide and inform talent development is yet to be undertaken within RL in Australia.

2.4.2 Soccer

Similar to both RL and AF, soccer is a team invasion sport that requires players to possess a range of physical, technical, and tactical skills during competitive games (Keller, Raynor, Bruce, & Iredale, 2016, 2018; Keller, Raynor, Iredale, & Bruce, 2018). However, traditionally, studies in soccer talent development have focused heavily on measuring the physical attributes and abilities to assess and compare player performance (Diallo, Dore, Duche, & Van Praagh, 2001; Philippaerts et al., 2006; Silvestre, West, Maresh, & Kraemer, 2006). For example, Gonaus et al. (2012) examined physical qualities of junior soccer players aged 14 to 17 years and reported that soccer-specific speed and upper limb power discriminated future playing status, irrespective of age category. Further, Roescher et al. (2010) reported that Dutch elite juniors (14-18 years), discriminated their non-elite peers in measures of standing height and body mass, while also recording faster interval shuttle times. Expanding their findings, the authors suggested that talent development programs in soccer should focus training activities around the development of repeated sprint capacity to enable a smoother transition through a pathway (Roescher, Elferink-Gemser, Huijgen, & Visscher, 2010).

Recently, though, there has been a greater appreciation within the literature regarding the examination of the technical and tactical skills important for talent development in soccer (Williams et al., 2020). Notably, Keller et al. (2016) demonstrated that technical skill tests in soccer were capable of differentiating talent identified and non-identified players within a Australian development pathway. Specifically, national U18 players demonstrated pronounced technical skills for passing (long and short), shooting, and ball control relative to their sub-elite peers (Keller et al., 2016). Accordingly, it was unsurprising to note that technical skills (i.e., passing capability) were shown to be a key predictor of future career success within soccer (Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2014; Leyhr, Raabe, Schultz, Kelava, & Höner, 2019; Zuber, Zibung, & Conzelmann, 2016).

Similar to the research in AF described earlier, successful soccer performance has been shown to be achieved through different combinations of performance characteristics (i.e., physical, technical, and tactical) (Williams et al., 2020). Research within the talent pathway in soccer is now supporting this multidimensionality by examining more than just the physical components of game play. Moreover, by comparing these components across a range of developmental levels, practitioners within the game (both locally and internationally) are afforded opportunities to design evidence-based talent development pathways and training activities.

Summarising to this point, I have discussed a theoretical framework that advocates the multidimensional (i.e., physical, technical, and tactical) requirements of game play in team sports. Building from this, I have discussed what is meant by the word 'talent' and have detailed two main and competing theoretical models of how it is developed in sport. I then discussed talent development research within AF and soccer that has emphasised the physical, technical, and tactical components of game play, with the results of such research being of use to support practitioners in developing talent within those respective team sports. Accordingly, the next sections of this review adopt a more specific focus on RL, starting with a detailed insight into the research that has explored the physical, technical, and tactical components of game play. In doing so, I highlight the current gaps within this research surrounding talent development and demonstrate how the research chapters within this thesis will endeavor to fill them.

2.5 The Multidimensional Requirements of Game Play in Rugby League

As briefly discussed in Chapter 1, RL is a team invasion sport that requires participants to perform a range of skills that can broadly be categorised into physical, technical, and tactical components. Shown in Table 1, there has been a wide variety of research that has examined these qualities across the entire developmental spectrum in RL (i.e., from elite senior to sub-elite junior competitions). This research has provided a robust platform for both researchers and practitioners, guiding the design and implementation of game strategies, training activities and developmental practices (Table 1). For example, research has detailed the physical profiles of NRL players according to their playing position, demonstrating pronounced positional differences between outside backs and forwards, information which would implicate the training practices of players in these positions (Table 1) (Gabbett, Jenkins, & Abernethy, 2012). Further, Gabbett and Hulin (2018) showed that successful NRL teams (as demonstrated by a higher end of season ranking) possessed more pronounced technical and tactical involvements (e.g. more effective passes, more offloads, and fewer missed tackles) in contrast to their lower ranked counterparts (Table 1). Information such as this would be critical for coaches and analysts working within the NRL, logically being used as a basis to design practice activities that enable the development of such technical (e.g., offloading) and tactical (e.g., affecting a tackle) skills. Collectively, this large amount of research has examined the demands of RL game play and undoubtedly improved training and development practices both in Australia and abroad. The next sections will discuss some of this research in more detail, specifically the physical, the technical and the tactical performance qualities that are demonstrated in RL game play.

Table 1. Examples of RL research that have examined the physical, technical, and tactical qualities of players across the junior-senior continuum.

	Reference	Variables	Cohort	Main results
Physical	Atkins (2006)	YoYo Intermittent Recovery Test and its relationship to performance, heart rate response, and blood lactate measures	ESL Senior elite vs senior sub-elite (UK)	Descriptive statistics suggested that elite players achieved greater total distance, and sub-elite had lower blood lactate values. However, no significant differences were noted.
	Dempsey et al. (2018)	Microtechnology used to assess the physical (i.e., running, and collisional) demands of game play	ESL Senior elite vs junior elite (U18) (UK)	Senior players were heavier and taller than juniors. Senior players also performed significantly more defensive collisions and ball carries into contact when compared to the junior players.
	Dobbin et al. (2019)	Standing height, body mass, sprint time, countermovement jump height, maximal aerobic capacity, and upper body power. Differences between player levels within the same age group.	Junior elite (U19) (UK)	3^{rd} year players were slower compared to 1^{st} and 2^{nd} year. Both 2^{nd} and 3^{rd} year were heavier than 1^{st} year. Position variability was noted for speed, power, and aerobic capacity.
	Gabbett et al. (2007)	Skinfolds, standing height, body mass, stationary vertical jump height, linear speed, agility, maximal aerobic power, general skills, evasion skills tackling and offensive skills.	Senior competition for metropolitan players 18-28 years (Aust)	Physiological and anthropometric measures were consistent across three groups but first grade players were significantly greater for basic passing, ball carrying, tackling, defensive and evasion skills compared to second and third grade players.

Reference	Variables	Cohort	Main results
Gabbett et al. (2009)	Skinfolds, standing height, body mass, stationary vertical jump, linear sprint time, change of direction, maximal aerobic power, and tackling assessment.	Junior elite vs sub-elite (U16) (Aust) (starters vs. nonstarters)	Elite players possessed superior change of direction times, vertical jump heights, and maximal aerobic power. For both groups, starters were taller, heavier, had a greater VO_{2max} compared to non-starters.
Gabbett et al. (2012)	Microtechnology to compare physical demands of position, competition, and training.	Senior elite NRL (Aust)	Demands differed between positions, with training practices not reflecting these physical demands.
Gabbett & Hulin (2018)	Microtechnology used to compare the physical demands of competition across 10 years.	Senior elite NRL (Aust)	Changes over 10 years. include decreases in maximum ball in play, increases in short duration ball in play, increased short duration recovery, and decreased long duration recovery periods.
Geeson-Brown et al. (2020)	Body composition differences by age level – systematic review and meta-analysis.	Senior elite ESL vs senior sub-elite vs junior elite (U19) vs junior sub-elite (UK)	Fat free mass (FFM) for backs were higher in senior elite compared to senior sub-elite, but not junior elite. FFM for forwards was higher than the backs all groups and bone mineral content was highest for elite senior backs.
Glassbrook et al. (2019)	Meta-analysis of distances covered, repeated high-intensity efforts and number of collisions performed during game play.	Senior elite NRL (Aust) vs ESL (UK)	Forwards had less playing time, recorded less low speed and high-speed distances. However, they did complete more repeated high-speed efforts and collisions compared to backs.

Reference	Variables	Cohort	Main results
	Comparisons of squads and player position.		Further, adjustables had shorter playing time, greater low speed distances and total relative distances compared to backs.
Hulin & Gabbett (2015)	Microtechnology used to assess the physical demands of competition.	Senior sub-elite (Aust) successful vs less successful teams	Successful teams had a greater involvement of forwards in collision activities and maintained greater ball possession time.
Ireton et al. (2017)	Body mass, standing height, isometric strength, power, athletic assessment ability.	Elite senior, U19 and U16 academy players (UK)	Elite senior players obtained a superior score on the AAA, were stronger and had a greater peak force compared to the U19 and U16 players.
Speranza et al. (2015a)	The relationship between strength and tackling ability. Upper and lower body strength, upper and lower body power.	Senior sub-elite vs senior metropolitan vs U20 metropolitan players (Aust)	A positive and significant relationship was noted between maximum squat and bench press and tackle ability across all groups. No significant differences for tackling ability.
Till et al. (2013)	Longitudinal insights into standing height, body mass, sum of seven skinfolds, lower and upper body power, speed.	U13, U14 and U15 years Academy (UK)	Authors suggested the different development trajectories that occur during adolescence have implications for individual long-term monitoring and assessment for junior RL players.
Till et al. (2014a)	Standing height, mass, skinfolds, vertical jump, upper body power, strength, running speed, VO_{2max}.	U14 vs U16 vs U18 vs U20 years Academy (UK)	Authors evaluated seasonal changes in physical characteristics over one football season. Characteristics are influenced by age category.

	Reference	Variables	Cohort	Main results
	Till et al. (2015a)	Standing height, sum of seven skinfolds, power, speed, upper body power, agility and maximal aerobic capacity - long-term performances in RL pathway.	13 vs 15 years Academy (UK)	A low sum of seven skinfolds measure, stationary vertical jump height, linear sprint speed, change of direction and estimated maximal aerobic capacity appeared most explanatory of long-term career success.
	Till et al. (2016)	Standing height, mass, skinfolds, power, upper body power, strength, running speed, VO_{2max} comparisons.	U17 vs U18 vs U19 years Academy (UK)	Differences between groups for height, bench press, squat, prone row. Concluded that advanced physical qualities were important to progress to elite competitions.
	Twist et al. (2014)	Microtechnology used to assess physiological demands of competition.	Senior elite NR vs senior elite ESL	NRL game play had higher sprint distances and less low to moderate distances, suggesting NRL have superior maintenance of aerobic output and higher standard of game play.
Technical	Austin et al. (2011)	Game play tackling demands comparing player positions.	Senior elite NRL (Aust)	Movements prior to effecting tackle are striding and sprinting. Hit-up forwards were involved in low intensity activity prior to tackle compared to adjustables and outside backs.
	Gabbett et al. (2010)	Skinfolds, height, body mass, stationary vertical jump height, acceleration, agility, tackling	Junior elite (NRL academy) vs metropolitan juniors (U16) (Aust)	Junior elite players were taller, heavier, leaner, had superior acceleration and agility and tackle skill compared to sub-elite players.

	Reference	Variables	Cohort	Main results
	Gabbett et al. (2011b)	Skinfolds, standing height, mass, vertical jump, speed, aerobic capacity, agility, tackling and passing ability, pattern recall/prediction.	Senior elite NRL (Aust)	Selected players were older, leaner, had greater playing experience, possessed superior speed and muscular power, maximal aerobic power, and had greater tackling skill. No difference between groups for pass ability.
	Gabbett (2014)	Microtechnology used to compare game demands between successful and less successful teams.	Senior sub-elite (Aust)	Successful teams performed fewer moderate tackle collisions, gained more and conceded less metres, and had faster play-the-balls compared to less successful teams.
	Speranza et al. (2015b)	Relationship of task scores for tackle skill, player position, strength, power, and match play tackle skill.	Senior sub-elite (Aust)	Higher scores in a tackle assessment correlated with effective tackles and fewer missed tackles during competition. Successful tacklers lower body strength was superior to less successful peers.
	Woods et al. (2017b)	Game play characteristics comparing developmental levels	Senior elite NRL vs junior elite (U20) (Aust)	NRL players performed a greater number of all runs, had more effective tackles and missed fewer tackles compared to U20 players. Authors suggested emphasis on U20 tackle skill to aid transition.
Tactical	Connor, Crowther, and Sinclair (2018)	Anticipation and visual behaviour comparisons for decision-making from a defensive perspective.	Senior elite (NRL) vs non RL control group	Elite players had superior anticipation for predicting side and split step evasion manoeuvres compared to control group.

Reference	Variables	Cohort	Main results
Cupples & O'Connor (2011)	Coaches perspectives on talent identification using cognitive, physiological, and skill indicators.	RL development coaches at the U20 level	Results suggested that communication, mental toughness, reading game play and decision-making skill were the most influential factors perceived to identify talent at the U20 level.
Gabbett et al. (2011c)	Assessment of single and dual task draw and pass technique – intervention for pre and post training results.	Junior elite (U20) vs junior sub-elite (Aust)	Junior elite players possessed reduced attentional demands compared to sub-elite peers during a pass and draw assessment. Authors suggested that dual task training may offer benefits that transfer to competition performance.
Johnston & Morrison (2016)	Interview conducted to measure recall and prediction of game play cues.	Senior elite NRL vs sub-elite (Aust)	Elite players processed cues differently to sub-elite and chose more salient indicators from opposition, leading to superior prediction accuracy in decisions.

AAA = Athletic Ability Assessment; ESL = European Super League; NRL = National Rugby League; Aust = Australia; UK = United Kingdom; RHIE = repeated high intensity effort; VO_{2max} = maximal volume of oxygen consumed during exercise.

2.5.1 The Physical Qualities of Rugby League

As shown in Table 1, a large proportion of the research in RL has primarily focused on the physical components of the game. Despite its multidimensional nature (i.e., requiring physical, technical, and tactical components), this trend in the literature was somewhat unsurprising given the heavy collisional nature of game play. This research has identified a range of physical qualities critical for a successful performance across both elite senior and junior competitions (Geeson-Brown et al., 2020; Ireton et al., 2017; Woods et al., 2017b). For example, in a comparison of elite senior competitions, Twist et al. (2014) noted that game play within the NRL was generally categorised by a greater distance covered at high-speed running velocities and lower distance covered at moderate and low speed running velocities when compared to the European Super League (ESL) competition. Johnston et al. (2019) further suggested that NRL players endured greater collision frequency compared to the ESL and possessed better maintenance of average speed as collision frequency increased. These studies suggested that the development of RL juniors may require a separate approach, as the demands of the senior elite levels were distinctly different.

With a specific focus on RL in Australia, research demonstrated the importance of lower and upper body strength (as measured via back squat and bench press maximal repetition tests) for the performance of successful (i.e., unbroken) tackles in first grade competitions (Speranza, Gabbett, Johnston, & Sheppard, 2015a). This research indicated that although technique was important (discussed in section 2.5.2 below), there was an underlying requirement of strength likely needed to enforce a successful tackle in RL (Speranza et al., 2015a). Further, research has identified the importance of physical precocity for identification onto elite RL development programs within Australia. For example, Gabbett et al. (2009b) noted that junior players identified onto an elite development program generated greater lower limb power and possessed higher levels of lean body mass in comparison to their non-identified counterparts (a further description of these physical tests can be seen in Table 1). When coupled to the findings of Speranza et al. (2015a), research such as Gabbett et al. (2009b) suggests that physical skills likely transfer into the successful performance of on-field actions such as tackling, line-breaks (e.g., where a player from the same team breaches the opposition defensive line) and offloads (e.g. passing).

However, not only important for talent identification, and of relevance to this thesis, differences in physical capability have been shown between participants currently within an elite talent development pathway (Table 1). For example, Ireton et al. (2017) demonstrated that elite senior RL players within a talent development academy possessed superior athletic movement competency, greater body mass and generated superior lower body power when compared to their junior counterparts. Further Dobbin et al. (2018) discussed physiological characteristics comparing differences between first, second and third year U19 players. However, while of value to practitioners within these talent academies, it is important to note that this research comparing levels within a talent academy was conducted within the UK, not Australia. This is an important consideration given the known differing game demands of the premier competitions within Australia (NRL) and Europe (ESL), as cited above by Twist et al. (2014). This suggests that the developmental requirements of talent identified players within a development pathway in Australia and the UK may be different. Importantly, though, research to date has yet to explore the physical and anthropometric differences of players at different stages of a talent pathway in Australia; a gap this thesis aims to address.

2.5.2 The Technical Qualities of Rugby League Game Play

Technical skills can be defined as fundamental actions that are specific to a sport, with examples in RL being tackling and ball passing (Gabbett, Stein, Kemp, & Lorenzen, 2013). Interestingly, in comparison to the physical components of the game, there have been few examinations of the technical skills for RL game play (Table 1). While physical and anthropometric precocity was shown to be important for success in the game, recent research showed that the performance of technical skills in RL, such as tackling, passing and kicking, differentiated successful and less successful teams within senior sub-elite competitions (Hulin & Gabbett, 2015). Specifically, higher ranked sub-elite teams (categorised by end of season ladder position) completed a greater number of successful passes and missed fewer tackles when compared to teams ranked lower on the ladder (Hulin & Gabbett, 2015). Further, first grade RL players were shown to possess superior passing and tackling skill when compared to second and third grade players, despite players in all competitions possessing similar physical qualities (Gabbett, Kelly, & Pezet, 2007). These studies highlighted that although physical precocity was important for RL game play, other skills (e.g. fundamental technical skills captured in passing and tackling capability) were also crucial to player development and success.

2.5.2.1 Tackling Skill

The tackle is a key defensive skill in RL, being used to stop an opponent from progressing the ball toward their scoring line (Gabbett, Jenkins, & Abernethy, 2010; Speranza et al., 2015a; Speranza, Gabbett, Johnston, & Sheppard, 2015b). Its importance for game play has been shown with Hulin and Gabbett (2015) who noted that successful tackle involvements, completions, and fewer missed tackles were characteristic teams ranked higher on the ladder at the end of the season. Interestingly, the total number of effective tackles and tackle involvements recorded during game play was shown to differentiate the NRL and an elite junior competition within Australia (Woods et al., 2017b). The authors suggested that the differences between these two playing levels may be partially explained by greater exposure to specialised training interventions intended to improve tackling skill and that elite junior competitions may not be preparing players for the ensuing tackling requirements of the NRL (Woods et al., 2017b). While these results were of critical relevance to this thesis, the authors did not identify where these differences emerged from – namely, were the juniors missing more tackles during game play because of key technical inefficiencies during the tackle? The research from Speranza et al. (2015b) suggests this may be the case, noting that players with good tackling skill (defined through the identification of key technical coaching points) were involved in a higher proportion of dominant tackles and fewer missed tackles during competition. Accordingly, it would be important to identify where the specific tackling inefficiencies occur within talented juniors, which could create the basis for the targeted tackle-specific training interventions highlighted by Woods et al. (2017b).

2.5.2.2 Passing Skill

In contrast to the tackle, passing the ball in RL is a fundamental offensive skill that enables an attacking team with the opportunity to advance closer to the scoring line (Gabbett et al., 2007). For example, a RL player's capacity to create a line-break was dependent on a skilful pass (Gabbett, Jenkins, & Abernethy, 2011b). Thus, given its centrality to the game, passing skill was shown to be discriminant of identification onto an elite senior (Gabbett et al., 2011b) and junior RL team (Gabbett, Wake, & Abernethy, 2011c). Notably, Gabbett et al. (2011c) compared the draw and pass ability of elite and sub-elite junior RL players, demonstrating that the elite junior group had greater consistency in terms of passing accuracy relative to their sub-elite counterparts when measured using a pre-determined passing skill criterion.

2.5.3 The Tactical Requirements of Rugby League Game Play

In further contrast to the quantity of research conducted on the physical and technical components of RL, there has been limited research (to date) examining the tactical, or decision-making skill of players (Table 1). In part, this could be due to the quantity of decisions that players have to make during game play, such as deciding who to pass the ball to, when to attempt to penetrate a defensive line, how to evade an opponent, or whether to leave a defensive line to support a teammate making an effective tackle. This difficulty in capturing and understanding the decision-making skill of RL players may be further complicated with the extent of offensive (with ball possession) and defensive (opposition in ball possession) decision categories. For example, defensive decisions could include aspects such as where to position oneself to impede a pass, when to create a tackle or assist a teammate in making a tackle, and when to hold position on the defensive line (Hendricks, Lambert, Masimla, Durandt, & Gabbett, 2015). Comparatively, offensive decisions could include aspects such as who to pass the ball to and when, where to position oneself to receive the ball, and how to manoeuvre oneself to avoid being tackled by an opponent (demonstrating evasive skill) (Hendricks et al., 2015).

In an effort to measure the offensive decision-making skill of players, Gabbett et al. (2011c) compared the attentional demands of U20 RL players (split into talent identified and non-talent identified groups) during a dual task, pass and draw offensive assessment. The talent identified group generally performed the assessment with little reduction in performance outcome (pass accuracy) when a secondary task was added compared to the non-talent identified group (Gabbett et al., 2011c). Further, others have examined the offence decision-making skill of elite and sub-elite RL players, captured during a video-occlusion decision-making task (Connor et al., 2018). Results demonstrated that elite players were able to more accurately predict an evasive manoeuvre performed by the ball carrier at the point of clip occlusion when compared to their sub-elite peers (Connor et al., 2018). Though, this video-based assessment required participants to only verbalise their response, as opposed to action it in context, and limits its applicability to game play due its methodological concerns (Bennett, Novak, Pluss, Coutts, & Fransen, 2019). Nonetheless, while the above research demonstrated that some differences exist in the offensive decision-making skill of RL players at different levels of expertise, there has been no research to date that has assessed the decision-making skill of RL players across a developmental pathway. This knowledge demonstrates the areas of tactical growth within a talent pathway and is likely to aid practitioners with the development of training activities, such as small-sided games (Gabbett et al., 2011c), intended to improve talent development in RL.

2.6 Current Gaps This Thesis Aims to Address

The physical, technical, and tactical requirements of RL game play have been examined in a range of studies largely focused on the physical components, fewer studies for the technical requirements and less on the tactical requirements. Nonetheless, the general theme from much of this research demonstrates that 'elite' players (categorised specific to the studies listed in Table 1) possess superior physical, technical, and tactical skills. This has led to evidence-based decisions about training designs and practices within a talent pathway to address identified performance gaps between levels (Ireton et al., 2017). Further, it has scaffolded the establishment of evidence-based pathway structures for UK academy RL (Till, Jones, & Geeson-Brown, 2016; Till et al., 2014b). However, despite this quality and quantity of research in RL talent development (Table 1), it has been primarily confined to the UK talent pathway. As such, research has yet to comprehensively compare the physical, technical, and tactical skills of RL players across a structured talent pathway (i.e., across junior to senior levels) in Australia – an important gap in the literature for RL.

The gaps within the literature raise some important questions that this thesis endeavors to address. Namely, if the performance gaps between developmental levels within an Australian talent pathway are unknown, what are practitioners basing the design of training activities intended to development talent on? Further, although structured development pathways, such as the Qld RLTP (Figure 1) have been established to support talented youth, is its current structure (i.e., U18 to U20 to SL) suitable? More specifically, is the gap between the U18 and U20 levels consistent with the gap between the U20 and the SL? By addressing questions such as these, practitioners working within RL development pathways in Australia, such as the Qld RLTP, will be able to base interventions and training designs around evidence, thereby more rigorously developing future elite RL players.

2.7 Thesis Aim

The overarching aim of this thesis was to *identify the physical, technical, and tactical performance qualities discriminant of developmental level within the Qld RLTP*. The three research questions that were developed to achieve this aim were:

1. Do **physical**, anthropometric, and athletic movement abilities discriminate developmental level within a RLTP?

   H_1: Physical, anthropometric, and athletic movement qualities will discriminate development level within a RLTP.

2. Do **technical** skills of passing and tackling discriminate development level within a RLTP?

   H_1: Passing and tackling qualities will discriminate developmental level within a RLTP.

3. Does **tactical** skill, quantified via an evasion task, differentiate developmental level within a RLTP?

   H_1: Decision-making ability will differentiate developmental level within a RLTP.

Chapter 3 Physical, Anthropometric and Athletic Movement Qualities Discriminate Development Level in a Rugby League Talent Development Pathway

Publication

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Author Contributions

L.A.P contributed 75% to this chapter. She developed the chapter structure, wrote each section, collected and analysed the data. Both C.T.W and A.S.L offered conceptual guidance and statistical support where required (15%), while W.H.S contributed to the manuscript drafting and construction of ideas within the discussion (10%).

3.1 Introduction

In an attempt to acquire sporting excellence, it is common practice for sporting organisations to integrate evidence-based learning environments to assist with talent development (Phillips et al., 2010). The fundamental goal of these learning environments, typically referred to as 'academies', is to accelerate the development of performance qualities deemed critical at the elite senior level, thus expediting the elite junior-to-senior transition (Phillips et al., 2010). Examples of these talent development academies have been reported in team invasion sports such as AF (Woods et al., 2016a), soccer (Williams & Reilly, 2000) and field hockey (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2007). Within each of these examples, 'developmental benchmarks' (defined as reference values that discriminate developmental levels) were identified and utilised as a basis for orienting training interventions purported to expedite the junior-to-senior transition.

Like the aforementioned sports, RL is a multidimensional team invasion sport. It requires players to demonstrate physical qualities such as agility, acceleration, power, speed and the capacity to execute repeated bouts of high intensity activity (Till et al., 2017), in addition to technical (passing and tackling) and tactical (decision-making) qualities (Johnston et al., 2014). Conceivably, identifying physical fitness and anthropometric qualities explanatory of developmental level would, therefore, offer practitioners with an initial model to orient developmental interventions and guide talent development.

Given the importance of developmental benchmarking for talent development and player progression, several studies have examined performance differences between developmental levels in RL. For example, Ireton et al. (2017) compared the athletic movement skill and physical performance of elite senior and junior (academy representatives) English RL players.

Their results revealed that elite senior RL players possessed superior athletic movement skills (as defined via the athletic ability assessment; AAA) (Woods, Keller, McKeown, & Robertson, 2016b), had greater body mass and lower body power relative to their academy counterparts. While this research offers practitioners with a basis for developmental interventions intended to minimise these performance gaps, it is important to note that this research was conducted in an English system, which may generate transference difficulties to academies in other countries. Pertinently, there are known physical activity profile differences between players competing in elite senior RL competitions within Australia (NRL) and Europe (the ESL) (Johnston et al., 2019; Quinn, Sinclair, & Atkins, 2015). Notably, NRL players demonstrated superior relative high-speed running distances compared to ESL players, who engage in greater low and moderate-speed running during game play (Twist et al., 2014). It is, therefore, possible that junior players engage in nuanced talent development practices specific to their country of origin. As such, it remains unknown whether similar physical, anthropometric and athletic movement skill differences are present within an Australian RL development pathway.

In contrast to the English pathway that typically initiates from the U14 level, as shown in Chapter 1, the Australian RL development pathway is formally initiated at the U18 level, with players recruited into representative state league clubs from secondary school competitions (Figure 1). Following this, players then transition to the U20 level, and then if deemed capable, are selected onto a regional or SL team. The fundamental goal of this multi-level pathway is to develop RL players capable of competing within the elite senior competition; the NRL. The aim of this study was to compare the physical, anthropometric, and athletic movement qualities of talent identified RL players in the Qld RLTP. Given the research of others (Ireton et al., 2017), it was hypothesised that the SL athletes would possess superior athletic movement skills and lower body power characteristics relative to their U18 and U20 counterparts.

3.2 Methodology

3.2.1 Experimental Approach to the Problem

To test the study hypothesis, an observational cross-sectional research design was implemented. All participants undertook a test battery that consisted of physical, anthropometric, and athletic movement skill assessments. The test battery construction was in accordance with prior research in RL (Gabbett et al., 2011b; Ireton et al., 2017). Testing was performed at the end of the participant's preseason phase of training to standardise training related adaptations.

3.2.2 Participants

The total sample consisted of 174 participants who were registered within the same state based RL association. Each participant was categorised according to their developmental level (U18, U20 or SL), resulting in 52 U18 (17.2 ± 0.5 years), 53 U20 (18.9 ± 0.6 years) and 69 SL (23.8 ± 2.4 years) representatives. Playing position was standardised across each developmental level to ensure potential positional attributes did not impact the study observations. Ethical approval was granted from the relevant institution, with all participants and parents / guardians, if participants were <18 years of age, providing written informed consent prior to data collection.

3.2.3 Procedures

Participants undertook a battery of assessments: standing height, body mass, linear acceleration, agility, stationary vertical jump height, maximal aerobic capacity and athletic movement skill. Although the choice of each test was based on recommendations provided elsewhere (Ireton et al., 2017), a brief procedural description of each is provided below. Further, each test has shown to possess good reliability (Bangsbo, Iaia, & Krustrup, 2008; Barbero-Álvarez, Coutts, Granda, Barbero-Álvarez, & Castagna, 2010; Gabbett, Kelly, & Sheppard, 2008b; Rodriguez-Rosell, Mora-Custodio, Franco-Márquez, Yáñez-García, & González-Badillo, 2017).

Standing height was measured using a stadiometer and recorded to the nearest 0.1 centimeters (cm). Participants were required to remove footwear and were placed in the Frankfort plane prior to measurement.

Body mass was measured using a set of calibrated digital scales (Tanita BC545N Segmental Body Composition Monitor Scales BC-545N, Victoria, Australia). Participants were required to remove their footwear with body mass being recorded to the nearest 0.1 kg. Training shorts and a singlet were worn by all players.

Stationary vertical jump height was measured using a Vertec jump device (Swift Performance Equipment, Lismore, Australia). The participants performed three bilateral countermovement jumps at a self-selected depth with the best of three jumps recorded for analysis. At the highest point of each jump, the inside hand was used to displace the vanes of the Vertec apparatus. The jump height was recorded as the difference between the standing reach height and the highest vane displaced whilst jumping. The maximum jump height (in cm) was used as the criterion value for analysis. Additionally, peak lower limb power and average lower limb power generated by participants was estimated using the equation *78.5 x vertical jump cm + 60.6 x mass kg-15.3 x height cm – 1308*; and *41.4 x vertical jump cm + 31.2 x mass kg-13.9 x height cm + 431*, respectively (Johnson & Bahamonde, 1996).

Sprint time was obtained via a 30 metre (m) maximal sprint with five and 10m splits. Timing lights (Swift Performance Equipment, Lismore, Australia) were used to measure each split time with gates being placed at the start line, five, 10 and 30m distances. Three trials with two-minute rest intervals were conducted with the best time used for analysis.

Repeated sprint ability was measured via a six x 30m maximal sprinting effort on a 30 second (s) cycle (Pyne, Saunders, Montgomery, Hewitt, & Sheehan, 2008) using timing lights (Swift Performance Equipment, Lismore, Australia). Participants commenced each sprint in a stationary up-right position, placing their lead foot on the start line approximately 30cm behind the timing gate. Participants were given a five second warning prior to the commencement of each sprinting effort. The total time for all six sprints was used as the criterion for analysis.

Agility was assessed via the L-run agility test (Gabbett et al., 2008b). The L-Run test required participants to move as quickly forward and around 1.1m high poles placed in a pre-planned inverted capital 'L' design. Timing lights (Swift Performance Equipment, Lismore, Australia) were placed 2.5m apart at the start / finish line with the fastest time of three trials separated by three minutes used for analysis.

Aerobic capacity was measured using the Yo-Yo Intermittent Recovery Level 1 (IR1) test, similar to previous research (Atkins, 2006). The test concluded when the participant either: (a) reached volitional exhaustion, or (b) was unable to keep their running performance in time with the tones on two successive occasions. The total distance reached (in m) by each participant was used as the criterion value for analysis.

Athletic movement skill was measured via the modified version of the AAA (Ireton et al., 2017). This assessment included five trials each of an overhead (OH) squat, double lunge, single-leg Romanian deadlift (SLRDL) (movement completed on left and right legs), and an attempt to complete 30 push-ups (Woods et al., 2016a). Feedback was not provided to participants whilst performing the protocol in order to prevent a potential scoring bias (Frost, Beach, Callaghan, & McGill, 2012). Each movement was video recorded using standard two-dimensional cameras

(Sony CX405 Full HD Handycam, Singapore), placed in the sagittal and frontal positions. Each movement was demonstrated by the primary investigator prior to the assessment. Participants used a wooden dowel to simulate a barbell for the OH squat, SLRDL and double lunge movements (McKeown, Taylor-McKeown, Woods, & Ball, 2014). Scoring was conducted retrospectively using the video footage and criterions described elsewhere (McKeown et al., 2014; Woods, McKeown, Haff, & Robertson, 2016c). A greater description of each movement and its subsequent scoring criteria is provided in Table 2.

Table 2. The AAA used to assess athletic movement competency as adapted from Woods et al. (2016c).

Movement	**Assessment Points**	**3**	**2**	**1**
OH SQT	Upper Quadrant	Perfect hands above head / feet	Hands above head / feet	Unable to achieve position
	Triple Flexion	Perfect SQT to parallel	SQT to parallel (compensatory)	Unable to achieve position
	Hip Control	Neutral spine throughout	Loss of control at end of range	Excessive deviation
DL	Hip, Knee, Ankle	Alignment during movement	Slight deviation	Poor alignment
	Hip Control	Neutral hip position	Slight deviation	Excessive flex / ext
	Take off Control	Control	Jerking	Excessive deviation
Push Up	TB control	Perfect control / alignment	Perfect control / alignment for some	Poor body control for all reps
	Upper Quadrant	Perfect form / symmetry	Inconsistent	Poor scap. positioning for every rep
	x30 reps	Hits target count	-	< x 30
SL RDL	Hip Control – Frontal	Maintain neutral spine	Slight flex / ext through hips	Excessive flex / ext on SL stance
	Hip Control – Sagittal	No rotation	Slight rotation at end of range	Excessive rotation
	Hinge range	Achieves parallel	Can dissociate but not reach parallel	Cannot dissociate hips from trunk

Note: OH SQT, overhead squat; DL, double lunge; SL RDL, single leg Romanian deadlift; scap, scapula; flex, flexion; ext, extension

3.2.4 Statistical Analysis

To confirm the measurement properties of the AAA scoring procedure, the intra-rater reliability was assessed. The primary investigator assessed ten randomly chosen SL participants on two occasions separated by seven days. Given the categorical nature of the scoring criteria, the level of agreement between the two sessions was assessed using the weighted kappa statistic (k) (Landis & Koch, 1977). Agreement levels were defined as follows: <0 less than chance agreement, 0.01-0.20 slight agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 substantial agreement, and 0.81-0.99 almost perfect agreement (Landis & Koch, 1977).

Descriptive statistics (mean ± standard deviation) were calculated for all physical, anthropometric, and athletic movement skill criterion variables according to developmental level. A multivariate analysis of variance (MANOVA) modelled the main effect of development level (three levels: U18, U20 and SL) on each criterion variable, with the Type-I error rate set at $P \leq 0.05$. Additionally, effect sizes were calculated relative to the main effect using Cohen's d statistic, where d = 0.10-0.20 was considered small, d = 0.21-0.50 moderate, d = 0.51-0.80 large, and $d \geq 0.80$ very large (Cohen, 1992). All between group comparisons were performed using SPSS (version 21, SPSS Inc., USA).

Receiver operating characteristic (ROC) curves were built for the variables that were significantly different according to the main effect using SigmaPlot version 12.3 (Systat Software, San Jose, CA, USA). For each ROC curve, the area under the curve (AUC) was calculated with an AUC of one (100%) representing perfect discriminant power. The point on the curve of each variable that generated the highest AUC was considered the 'cut-off' value acceptable for discriminating between developmental levels.

3.3 Results

The level of agreement for scoring the athletic movement skill assessment ranged between 'substantial' to 'almost perfect' for each movement. There was a significant effect of developmental level ($V = 0.775$, F = 5.43, $P<0.05$) with the SL group superior to their U20 and U18 counterparts, demonstrating large effect sizes for measures of body mass, peak and average lower limb power, double lunge (left side), SLRDL on both left and right sides, the push up and total AAA score ($d = 0.68 – 1.21$; Table 3). Additionally, the SL group outperformed their U20 counterparts in the score for OH squat (Table 3), while the U18 group performed the double lunge movement with a significantly lower proficiency relative to both the U20 and SL levels (Table 3).

Table 3. Between group effects for anthropometric, physical and athletic movement skill assessments.

Variables	**U18**	**U20**	**SL**	**U18 – U20**	**U18 – SL**	**U20 – SL**
				d (90%CI)	*d (90%CI)*	*d (90%CI)*
Standing height (cm)	179.9 ± 7.0	179.2 ± 6.3	180.2 ± 13.5	0.11 (-0.22, 0.43)	-0.03 (-0.33, 0.28)	-0.09 (-0.39, 0.21)
Body mass (kg)	83.8 ± 11.2	85.5 ± 11.1	96.7 ± 12.3[ab]	-0.15 (-0.47, 0.17)	-1.09 (-1.41, -0.76)	-0.95 (-1.26, -0.63)
Vertical jump height (cm)	58.5 ± 6.1	58.0 ± 7.3	60.6 ± 7.6	0.07 (-0.25, 0.07)	-0.30 (-0.60, 0.01)	-0.35(-0.65, -0.04)
Peak lower limb power (W)	5606 ± 673	5686 ± 698	6551 ± 829 [ab]	-0.12 (-0.44, 0.21)	-1.24(-1.56, -0.90)	-1.12 (-1.43, -0.79)
Average lower limb power (W)	2965 ± 335	3010 ± 354	3452 ± 444 [ab]	-0.13 (-0.45, 0.19)	-1.22(-1.54, -0.88)	-1.08(-1.40, -0.76)
30m sprint time (s)	4.3 ± 0.2	4.2 ± 0.2	4.3 ± 0.2	0.55 (0.22, 0.87)	0.19 (-0.12, 0.49)	-0.39(-0.69, -0.09)
Agility time - left (s)	8.6 ± 0.4	8.7 ± 0.4	8.7 ± 0.4	-0.25(-0.57, 0.07)	-0.25 (-0.55, 0.05)	0.00 (-0.30, 0.30)
Agility time - right (s)	8.6 ± 0.4	8.6 ± 0.4	8.8 ± 0.7	0.00 (-0.32, 0.32)	-0.34 (-0.64, -0.03)	-0.34(-0.64, -0.03)
Repeated sprints total time (RSA) (s)	27.7 ± 1.1	27.6 ± 1.3	27.9 ± 1.4	0.08 (-0.24, 0.40)	-0.16 (-0.46, 0.15)	-0.22 (-0.52, 0.08)
Yo-Yo IR1 total distance (m)	909.2 ± 313.1	893.8 ± 368.7	960.0 ± 338.8	0.04 (-0.28, 0.37)	-0.15(-0.46, 0.15)	-0.19 (-0.49, 0.11)
Overhead squat	6.1 ± 1.6	5.6 ± 1.6	6.6 ± 1.7[b]	0.31 (-0.01, 0.63)	-0.30(-0.60, 0.00)	-0.60 (-0.91, -0.29)
Double lunge right	6.6 ± 1.1	7.1 ± 1.1[a]	7.5 ± 1.1[a]	-0.45 (-0.78, -0.13)	-0.82 (-1.13, -0.50)	-0.36 (-0.66, -0.06)
Double lunge left	6.4 ±1.0	6.7 ± 1.0	7.4 ± 1.1 [ab]	-0.42 (-0.62, -0.03)	-0.94 (-1.26, -0.62)	-0.66 (-0.97, -0.35)
Single leg RDL right	4.8 ± 1.0	5.3 ± 1.1	6.3 ± 1.3 [ab]	-0.48 (-0.80, -0.15)	-1.27 (-1.59, -0.93)	-0.82 (-1.13, -0.50)
Single leg RDL left	4.7 ± 1.0	4.8 ± 0.8	6.0 ± 1.1 [ab]	-0.11(-0.43, 0.21)	-1.23 (-1.55, -0.89)	-1.22 (-1.54, -0.89)
Push up	6.2 ± 1.5	6.2 ± 1.5	7.9 ± 0.8 [ab]	0.00 (-0.32, 0.32)	-1.47 (-1.80, -1.13)	-1.47(-1.80, -1.12)

[a] SL significantly ($P<0.05$) different to U18; [b] SL significantly ($P<0.05$) different to U20; L left, R right; *d* effect size

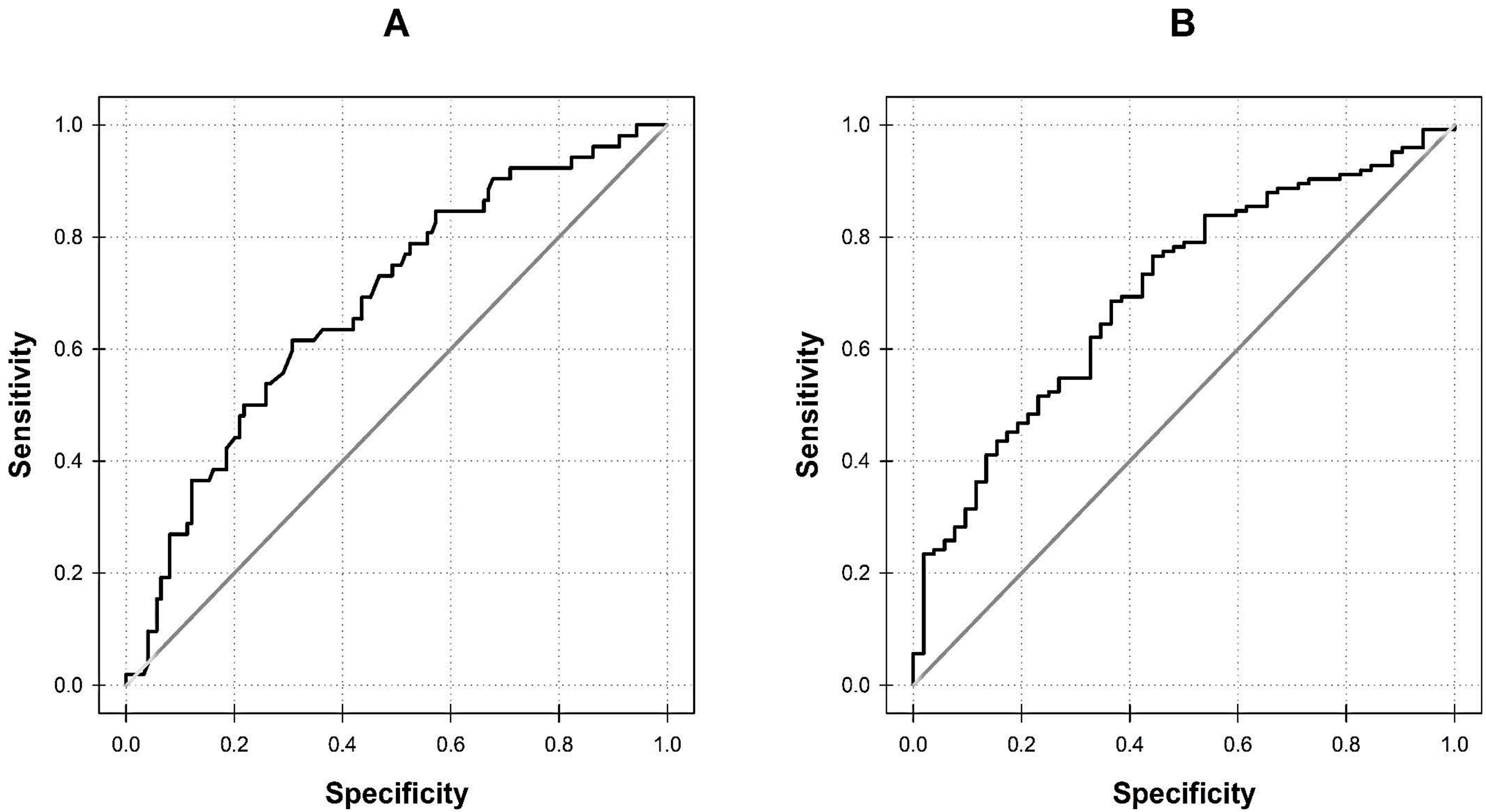

Figure 6. ROC curves showing the point generating the greatest AUC discriminating the combined U18 / U20 to the SL for: **A)** Body mass; **B)** Peak lower limb power.

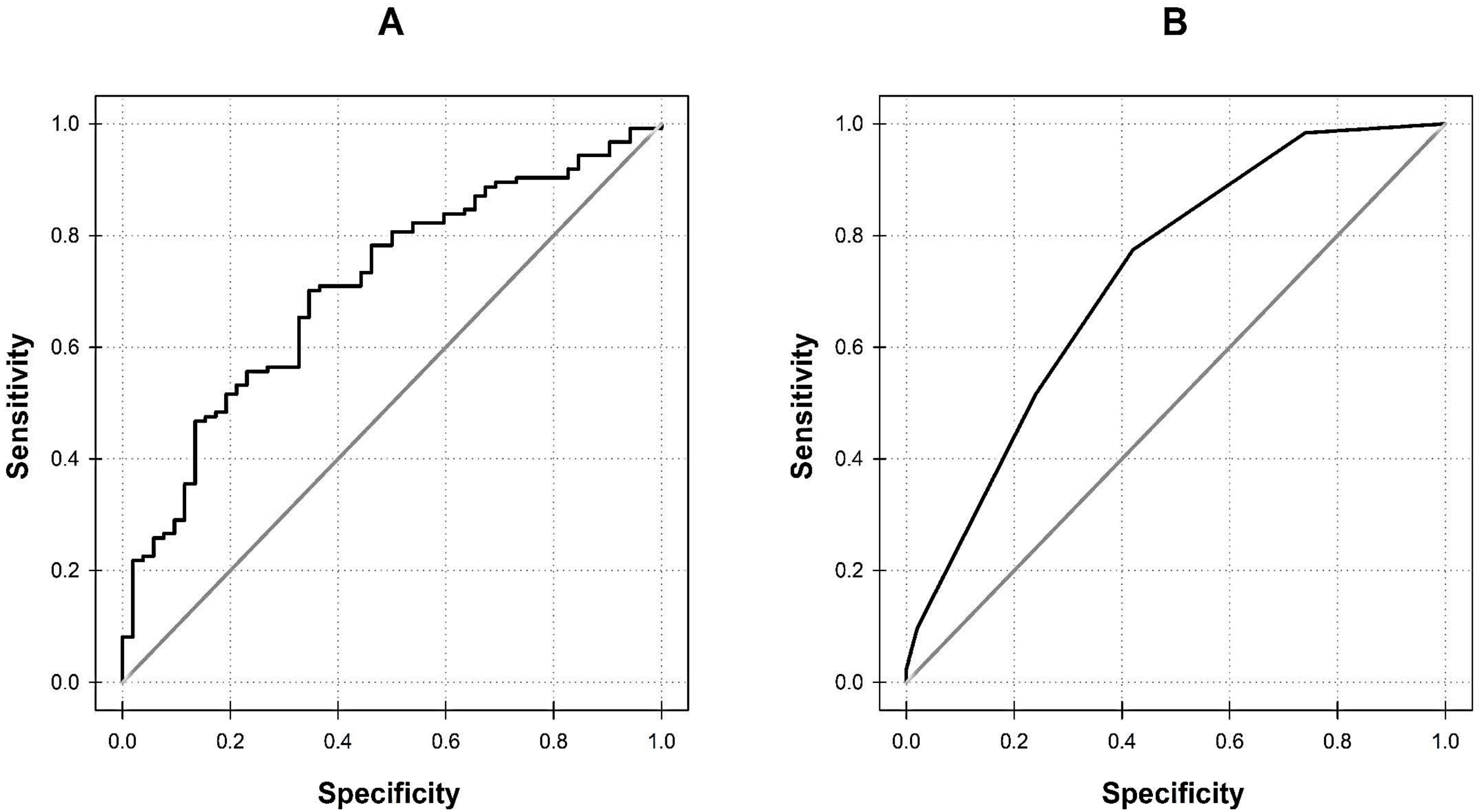

Figure 7. ROC curves showing the point generating the greatest AUC discriminating the combined U18 / U20 to the SL for: **A)** Average lower limb power; **B)** Double lunge score.

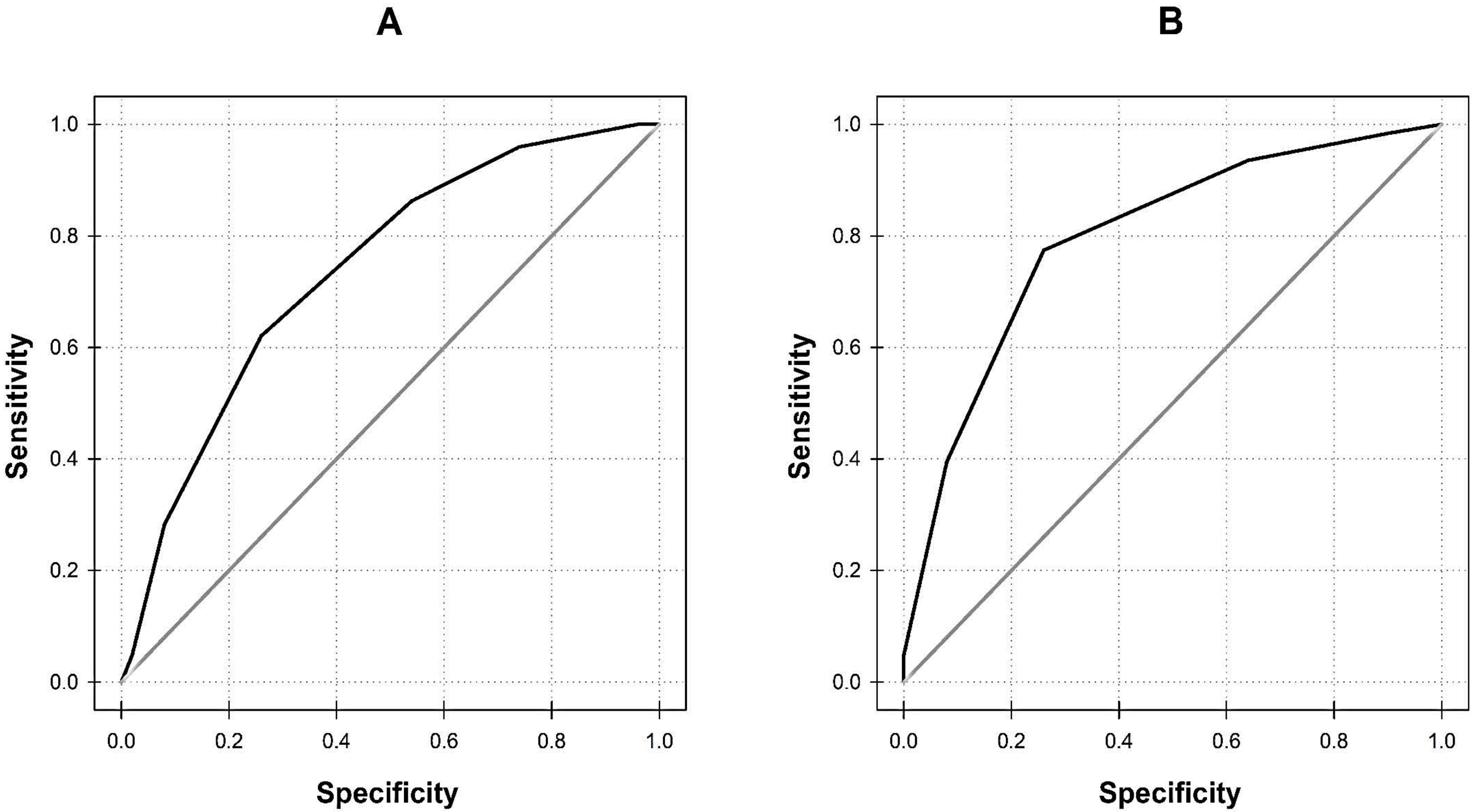

Figure 8. ROC curves showing the point generating the greatest AUC discriminating the combined U18 / U20 to the SL for: **A)** Single leg RDL – right leg score; **B)** Single leg RDL – left leg score.

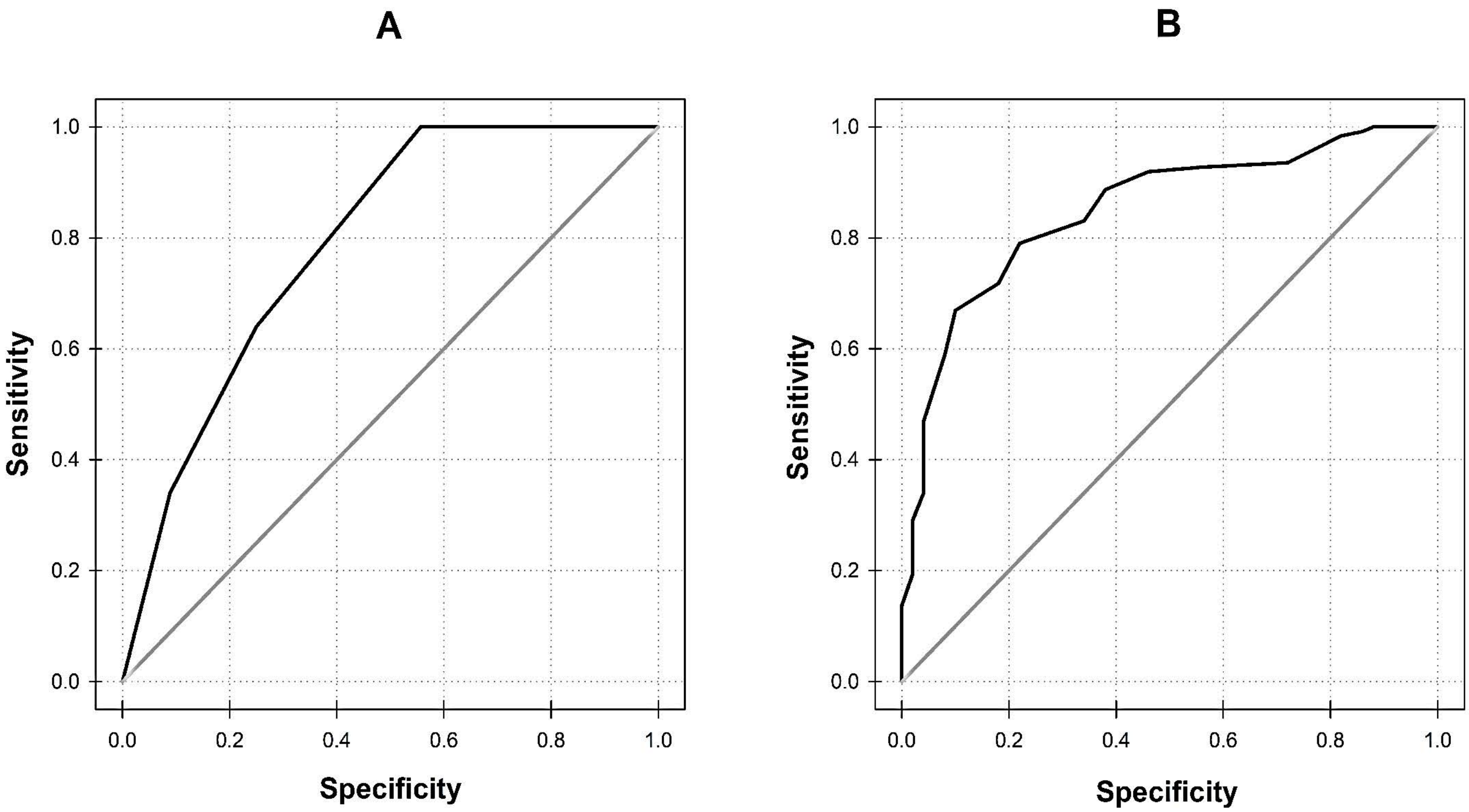

Figure 9. ROC curves showing the point generating the greatest AUC discriminating the combined U18 / U20 to the SL for: **A)** Push up score; **B)** Total AAA score.

Given the results from the MANOVA, the ROC curves compared two groups: the combined U18 and U20s (referred to as juniors), and the SL group (Figures 6 - 9). The variable expressing the greatest between-group discrimination was the AAA total score (Figure 9B). The 'cut-off' score for this was 39.6au (from a possible 54au) with the AUC being 85%. For the junior group, 79% of the participants scored ≤39.5au, whilst 78% of the SL group scored >39.5au. Regarding body mass ROC curves produced an AUC of 68.3% with mass of 85.5kg discriminating 69.4% of the combined U18 / U20 (did not achieve cut-off body mass of 85.5kg) and 61.5% of the SL (85.5kg or greater) (Figure 6A). Of the physical fitness assessments, peak lower limb power discriminated 76.6% of the juniors and 55.8% of the SL group at a score of 5635 watts (AUC = 70.1%; Figure 6B), while average lower limb power discriminated 70.2% of the juniors and 65.4% of the SL group at a score of 3040 watts (AUC = 70.8%; Figure 7A). The double lunge leg demonstrated an AUC 72.4%, successfully discriminating 77.4% of the juniors and 58% of SL group with a score of 7.5 (Figure 7B). The SLRDL right leg produced an AUC of 73.7%, with a score of 5.5au (out of a possible 9au) discriminating 62.1% of the junior group and 74% of the SL group (Figure 8A). The SLRDL left leg produced an AUC of 79.7%, with a score of 5.5 (out of a possible nine points or arbitrary units) discriminating 77.4% of the junior group and 74% of the SL group (Figure 8B). The push up score of 6.5au (possible 9au) (AUC 78.9) discriminated 55.6% of the juniors and 100% of the SL (Figure 9A).

3.4 Discussion

The chapter demonstrated that SL players outperformed their U18 and U20 counterparts in nine of the 17 criterion variables. Specifically, SL players were heavier, generated greater peak and average lower limb power, scored higher on the double lunge, SLRDL and push up movements, and subsequently had a higher AAA total score relative to the U18 and U20 players. These results provide coaches of U18 and U20 with objective insights into the physical and athletic movement qualities that differ between developmental levels in a Qld RLTP. Accordingly, these observations could generate practical utility for coaches responsible for the physical development of talent identified U18 and U20 RL players within a Qld development system.

It was of interest to note that the athletic movement skills of the U18 and U20 groups were considerably poorer than what was observed for their SL counterparts. Most apparent were the SLRDL and double lunge movements, where the U18 and U20 players performed at a lower standard to their SL representatives. The implications of these differences are important to consider as the SLRDL is often prescribed to assist with hamstrings and lumbar spine strength and motor control via eccentric loading (McKeown et al., 2014; Woods et al., 2016c). Additionally, the double lunge assists with the acquisition of lower body loading during acceleration and deceleration (Kuntze, Sellers, & Mansfield, 2009). The importance of athletic movement skill for physical performance outcome has recently been demonstrated in AF (Woods, McKeown, Keogh, & Robertson, 2017a) noting that junior AF players with relatively superior athletic movement were able to generate faster linear acceleration times, jump higher and produce a greater score on a 20m multistage fitness test. Thus, our results indicate that the majority of the U18 and U20 players may see augmented improvements with the continued refinement of their athletic movement capabilities.

Results showed that peak and average lower limb power were significantly different between the U18, U20 and SL groups. These findings complement the observations of Ireton et al. (2017) who demonstrated lower limb power differences between U16, U19 and senior English RL players. Taken together, it could be suggested that junior RL players may not yet possess the lower body power qualities required to match their senior counterparts. When coupled with the superior body mass shown by the SL players in the current study, it is possible that these power differences could negatively impact upon a U20 players progression into the SL when engaging in tackling and collisional activities performed during game play, such as line breaks and ball carries (Dempsey, Gibson, Sykes, Pryjmachuk, & Turner, 2018). To assist with training program design, practitioners could utilise the peak and average thresholds resolved from the ROC curve analysis. Notably, these values could provide reference points that coaches could use as targets for their U18 and U20 players that may assist with player progression. Pertinently, prior to undertaking advanced movements designed to enhance power, these results suggest that coaches at the U18 and U20 levels should prioritise the development of the athletic movement skills that underpin the SLRDL and double lunge movements.

The minor differences between the U18 and U20 developmental levels contrasted with Ireton et al. (2017) who observed differences in athletic movement, body mass and lower limb power between the U16 and U19 groups. These differences may be reflective of the age differences between the players used in both studies, with the U16 biologically immature relative to the U18 group. Further, the additional year of difference between the U16 and U19 group versus U18 and U20 in the current chapter may have impacted upon the magnitude of differences observed. Specific to this study, it is important to note that the U18 and U20 representative season is an eight-week competition opposed to the SL competition season, which is 25 weeks. Thus, a potentially reduced preseason phase of training within the U18 and U20 levels may result in the targeted development of the technical and tactical qualities needed in RL, constraining the development of the physical attributes described here. Nonetheless, this study demonstrates a clear developmental gap between the U18, U20 and SL levels with regards to physical attributes. Accordingly, to accommodate the temporal constraints imposed on the U18 and U20 levels, coaches could explicitly focus on the resolved differences presented here, using the ‘cut-off’ scores as a guideline for developmental benchmarking.

3.5 Practical Applications

There are three primary considerations to stem from this work. Firstly, the skill benchmarks highlighted by the ROC curve analysis may be used by coaches to improve player progression. Coaches for U18/U20 could implement programs with outcomes of AAA scores >5.5 and >7.5 for single leg RDL and double lunge movement, respectively. Secondly, coaching staff should focus on correcting bilateral and unilateral movement patterns prior to initiating a progressive-load resistance program. Finally, a focus on lower limb power generation for U18/U20 players.

Despite the practical implications of this research, it is important to acknowledge a repetition maximum strength test was not included due to time constraints. Future work should consider its inclusion to enable deeper insight into the physical capacities of players within the RL talent pathway. Further, RL is a multidimensional sport, requiring physical, technical, and tactical performance qualities (Gabbett et al., 2011c; Hendricks et al., 2015; Johnston et al., 2014; Till et al., 2017). Future research may therefore extend these findings by comparing the technical and tactical skills of RL players at different stages of a talent development pathway. This will subsequently enable insights into the multidimensional qualities that players require at different stages of development, and as such, will be specifically addressed in Chapters 4 and 5 to follow.

In conclusion, this study has highlighted the physical, anthropometric, and athletic movement skill differences between talent identified RL players within a development pathway in Qld. Results showed that SL players were heavier, possessed greater peak and average lower body power and athletic movement skill relative to their U18 and U20 counterparts. These observations are likely to provide coaches at the U18 and U20 levels with an evidence-based approach for the establishment of physical training interventions designed to positively augment talent development in the Qld RLTP.

Chapter 4 Passing and Tackling Qualities Discriminate Developmental Level in a Rugby League Talent Pathway

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Author Contributions

L.A.P. contributed 75% to this chapter. She developed the chapter structure, wrote each section, collected and analysed the data. Both C.T.W. and A.S.L. offered conceptual guidance and statistical support where required (15%), while W.H.S. contributed to the manuscript drafting, data collection and analysis (10%).

4.1 Introduction

It is common for sporting organisations around the world to identify juniors who are believed to possess the qualities capable of being developed into an expert, and expose them to opportunistic learning environments within a talent development academy (Vaeyens et al., 2008). Examples of these academies are reported within the literature (Elferink-Gemser et al., 2007; Williams & Reilly, 2000; Woods et al., 2016a), with their structure commonly consisting of multiple 'levels' that are driven by age groupings (e.g. U16, U18 and U20) (Gaudion et al., 2017). Consequently, it has been suggested that training practices prescribed within each age grouping should be informed by performance differences or gaps between these levels, thereby facilitating a smooth(er) transition along a developmental pathway (Gaudion et al., 2017; Pearce, Sinclair, Leicht, & Woods, 2018). This, however, requires an understanding of the qualities needed to succeed within the sport of choice, along with the performance differences evident between developmental levels.

As emphasised throughout this thesis, RL can be understood as a multidimensional team invasion sport that requires players to possess a range of physical, technical, and tactical performance qualities (Gabbett, Jenkins, & Abernethy, 2009a; Gabbett et al., 2012). Whilst these performance qualities are required for players at all developmental levels, certain physical and anthropometric qualities have been reported to discriminate participants at different levels of the RLTP (Ireton et al., 2017; Pearce et al., 2018; Till et al., 2016).

The third chapter of this thesis noted that peak and average power output, and athletic movement capability discriminated senior RLTP players from their junior counterparts within the Qld RLTP. Further, Ireton and colleagues (2017) suggested that senior elite RL players possessed superior athletic movement skills and greater lower body power relative to developmental pathway players. Whilst research, such as the aforementioned, provides practical guidance for talent development by highlighting physical performance gaps between age levels, it is important to note that a successful performance in team sport is typically the result of a range of multidimensional performance qualities (i.e., physical, technical, and tactical) (Launder, 2001).

It is likely that developmental differences are present for technical skill in addition to those physical qualities previously stated. Revealing potential technical performance qualities that discriminate developmental level may provide practitioners with knowledge to target technical skill development of talent identified RL players. However, this is yet to be examined within the Qld RLTP; the results of which may optimise athlete transition from junior-to-senior levels. Fundamental technical skills of RL game play have been identified as ‘passing’ and ‘tackling’ (Gabbett et al., 2007). Previous RL studies have suggested match analysis differences in the number of skill involvements between the more and less successful teams, as well as between the higher and lower ranked elite RL teams (Gabbett & Hulin, 2018). Successful teams controlled a greater portion of possession during competition and displayed an increased frequency of passing (Gabbett & Hulin, 2018; Hulin & Gabbett, 2015) compared to lower ranked teams. In particular, the cut out pass (received by the second, third or fourth player from the ball carrier), a more advanced passing skill, differentiated between successful and unsuccessful teams (Gabbett, Kelly, & Pezet, 2008a).

Tackles also discriminated successful and less successful teams. For example, in the 2017 season, the premiership winning NRL team recorded the highest number of effective tackles compared to lower ranked NRL teams whom exhibited a greater number of missed tackles (Gabbett & Hulin, 2018). In this study and others, a tackle was deemed effective and complete when the ball, or the forearm holding the ball, made contact with the ground, or the ball carrier was not able to continue moving forward with possession of the ball (Speranza et al., 2015b). To date, the skill differences between RL developmental levels are not known. Therefore, the aim of this chapter was to compare passing and tackling qualities of RL players at different levels of a talent developmental pathway. Given prior findings reported within Chapter 3, it was hypothesised that passing and tackling qualities would discriminate between developmental level in the RLTP.

4.2 Methodology

4.2.1 Experimental Approach to the Problem

As was done in Chapter 3, this study followed an observational, cross-sectional research design. All participants undertook a test battery that consisted of passing and tackling skill assessments. The test battery was in accordance with prior studies in RL (Gabbett, 2008; Hendricks et al., 2015; Speranza et al., 2015b). However, the addition of the 'cut-out' pass was included, which is a pass used to spread an opponent's defensive line, and is commonly performed over distances equal to, and greater than 7m. Further, the tackle criteria scoring was modified to account for the mode of front-on tackle the participant chose to execute (block, leg drive or ball and all tackle) (Corcoran, Levy, & Kelly, 2000; Speranza et al., 2017). The skill test battery was performed by participants during the mid-preseason phase of training to standardise training related adaptations. Prior to any testing, all participants undertook a standardised group warm up that included a physical and technical warmup and included a familiarisation of each test.

4.2.2 Participants

The total sample consisted of 88 participants from five RL clubs who were registered within the same state based RL competition. Each participant was categorised according to their developmental level (U18, U20 or SL), resulting in 27 U18 (17.1 ± 0.6 years), 29 U20 (18.3 ± 0.4 years) and 32 SL (23.6 ± 2.1 years) representatives. Similar to Chapter 3, playing position was standardised across each developmental level to minimise potential positional effects on results. Ethical approval was granted from the relevant human research ethics committee, and all participants provided written informed consent. Participants under 18 years provided assent prior to data collection, and written informed consent was also provided from a parent / guardian and participants.

4.2.3 Procedures

4.2.3.1. Passing Assessment

Passing skill was assessed across three distances: 4, 7 and 12m. The inclusion of the 12m cut out pass was assessed in addition to the 4 and 7m trials examined in previous passing studies (Hendricks et al., 2015). This was likely to account for the technical capacity of a long cut-out pass demonstrated in elite competition. Outcome measurements for passing were ball flight time and accuracy on both the left and right side. To initiate this assessment, each participant ran forward to a designated position 5m in front of them to receive a ball passed from a denoted ‘passer’ (Figure 10). Following this, the participant then continued to run (instructed to simulate competition pace) forward and release the ball (pass) to an adjacent ‘target player’ placed on either their left or right side (pending body side being assessed). The same ‘target player’ was instructed to run alongside the participant throughout the trial, similar to competition ‘run support’, omitting the need for a tactical ‘floating’ (slower) pass, within an adjacent marked corridor at each distance (i.e. matching distance being assessed) (Figure 10).

Three passing trials of each distance left-to-right and three trials right-to-left passing were carried out by all participants. The criterion variables included accuracy of the pass reception zone; ball flight speed (recorded from ball release to ball receive zone) of the pass and legality of the pass. The pass reception zone was categorically scored as below:

- **Six points** were awarded for zone 1 (defined by the ball being received between chin and umbilicus),
- **Three points** for zone 2 (defined by the ball being received in line to the chin with outstretched arms overhead),
- **One point** for zone 3 (defined by the ball being received between umbilicus and top of knees),
- **Zero points** outside these zones resulting in a maximum total of 18 arbitrary units (au) for each pass assessment.

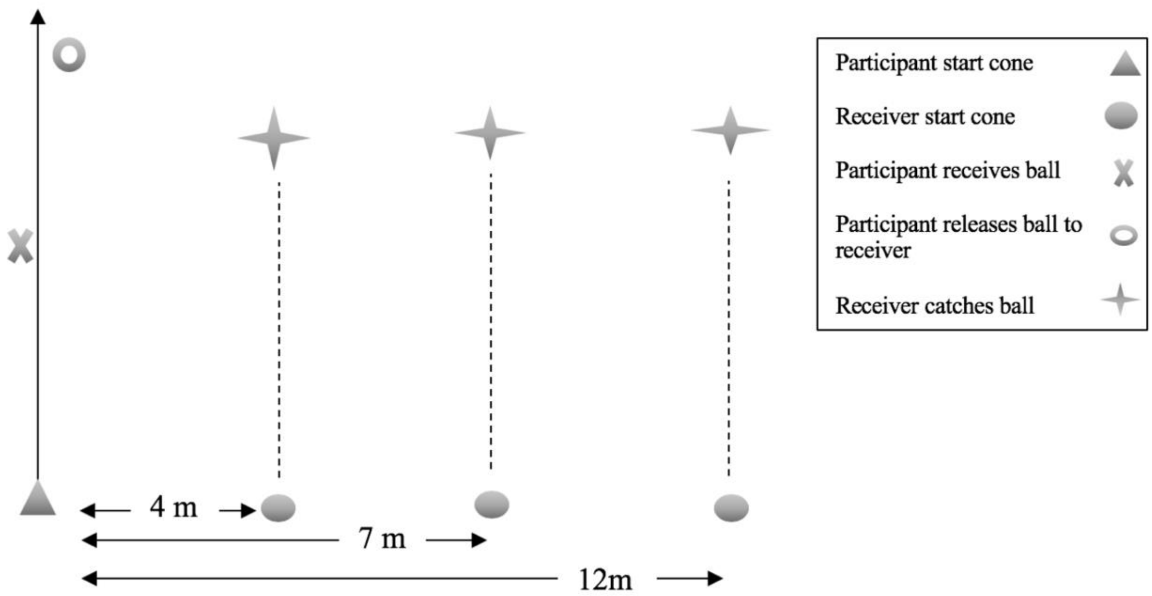

Figure 10. Field set up for RL passing skill assessment task.

A forward pass was deemed illegal and received a score of zero, being specifically noted during the video analysis. Forward pass criteria for the current study, was observation of the position of the ball within the receiving zone, this was to avoid penalising participant (ball carrier) due to receiver 'over run' error. One, two-dimensional video camera (Sony CX405 Full HD Handycam, Singapore) was positioned frontal to the release and catch, whilst a second two-dimensional video camera was placed perpendicular to the area participants executed their pass in order to determine whether the pass was forward (illegal) or behind (legal). The trials were video recorded and scored retrospectively for criterion variables: accuracy of the pass, ball flight speed and legality of the pass, using a dedicated software program (Rugby League Analyzer V4, Fairplay, Brisbane, Australia).

4.2.3.2. Tackling Assessment

Tackle skill was assessed by asking the players to perform a 'front-on, one-on-one' scenario. Video footage was recorded from perpendicular and front-on views to the collision zone using two, two-dimensional cameras (Sony CX405 Full HD Handycam, Singapore). The tackled player (ball carrier) and the participant (tackler) were instructed to run forward towards each other causing a collision ('hit-up') at a game speed that they would execute during RL competition. The ball-carrier was instructed not to evade the tackler.

For assessment of the front-on tackle, the current chapter chose the 'one-on-one' front-on tackle test previously shown to be a predictive assessment of tackle performance during competition (Speranza et al., 2015b). A modification to the test was employed to provide objective outcomes with greater ecological validity, as previously suggested (Waldron, Worsfold, Twist, & Lamb, 2014). The modification was an omission of instruction for which type of front-on tackle participants must execute, and addition of an instruction that the participant executes the tackle at competition intensity. To initiate the tackle assessment, the participant faced the ball carrier 8m apart from a static position. The participant and ball carrier were instructed to move toward each other, at a speed simulating game play, and collide (Figure 11). Execution of the tackle was deemed complete when the ball or the hand holding the ball made contact with the ground, and / or the ball carrier could not move forward (held-up) (Speranza et al., 2015b). Three trials with the participant using the right shoulder as the first point of contact were completed. A three-minute rest period was provided between each trial (a full tackle assessment lasted 20 minutes).

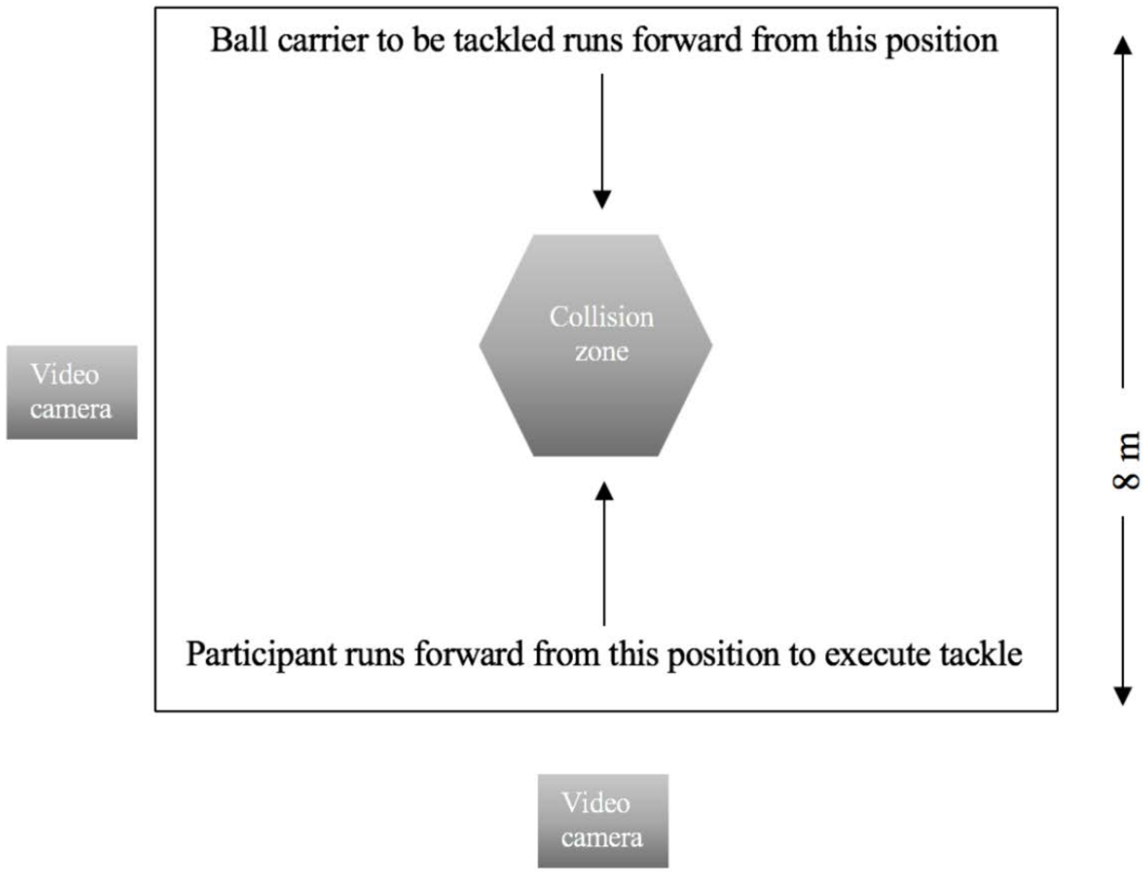

Figure 11. Field set up for RL tackling skill assessment task.

The current study recorded all front-on tackle types with each tackle type assessed according to a distinguishing set of criteria as previously suggested (Gabbett, 2008; Gabbett et al., 2011b; Speranza et al., 2015b) and in consultation with a Nationally ranked Level 3 RL coach (Table

4). To quantify tackling skill, a dichotomised scale was used with participants scoring one point for achieving each of the nominated criterion for the tackle type and zero if they did not achieve the criterion (Table 4). Additionally, 'failure to achieve any criteria' for each tackle mode at each developmental level was identified. Assessment was conducted retrospectively via video footage and participants were scored using the criteria that matched their tackle choice. The ball and all tackle criterion maximum score were nine arbitrary units, and the leg drive and the block tackle maximum scores were eleven and eight arbitrary units, respectively.

Table 4. One vs. one front-on tackle criteria for rugby league players.

Criterion for tackler	Tackle type
Stay tall – drop and drive at last moment*	Block and Leg drive
Shoulder contact at attackers' hip zone*	Block and Leg drive
Shoulders higher than hips upon contact*	Block and Leg drive
Initial contact with top of shoulder*	Block and Leg drive
Head in tight to attacker's body	Block, Leg drive, Ball and all
Arm wrap on attackers' hip and legs zone*	Block and Leg drive
Roll back or to side using attacker's momentum successfully*	Block
Body line front and square facing attacker	Block, Leg drive, Ball and all
Contact attackers' chest / shoulders	Ball and all
Step into contact	Leg drive, Ball and all
Contact the attacker with shoulder	Ball and all
Centre of gravity forward of base	Leg drive, Ball and all
Same shoulder and leading leg upon contact*	Leg drive, Ball and all
Lift / leg drive on contract	Leg drive, Ball and all
Chest / shoulder wrap to lever wrap*	Ball and all

*introduced tackle criteria by NRL Level 3 accredited coach

4.2.4 Statistical Analysis

Descriptive statistics (mean ± standard deviation) were determined for all passing and tackling skill criterion variables according to developmental level. A MANOVA modelled the main effect of developmental level (U18, U20 and SL) on each variable listed in Tables 5 and 6, with the Type-I error rate set at $P \leq 0.05$. Additionally, effect sizes were calculated relative to the main effect using Cohen's *d* statistic, where d <0.20 was considered trivial, d = 0.20-0.60 small, d = 0.61-1.20 moderate, d = 1.21-2.00 large and d >2.00 very large (Batterham & Hopkins, 2006). All between group comparisons were performed using SPSS (v21, SPSS Inc., USA).

As stated in Chapter 3, passing variables that were significantly different according to the main effect were discriminately analysed by means of ROC curves. For each ROC curve, the AUC was calculated with an AUC of one (100%) representing perfect discriminant power. The point on the curve of each variable that generated the highest AUC was considered the 'cut-off' value acceptable for discriminating between developmental levels. Additionally, tackle mode frequency was cross tabulated using chi square (χ^2) to note a significant relationship between competition and tackle choice.

Intra-rater reliability was assessed to substantiate measurement properties of the passing and tackle scoring criteria. The primary investigator randomly chose six SL participants to assess tackling and passing tests, on two occasions separated by ten days. The level of agreement between the two occasions was assessed using the weighted kappa statistic (κ) (Landis & Koch, 1977). Agreement levels were defined as follows: κ = <0, less than chance agreement; κ = 0.01-0.20, slight agreement; κ = 0.21-0.40, fair agreement' κ = 0.41-0.60, moderate agreement; κ =0.61-0.80, substantial agreement; and κ = 0.81-0.99, almost perfect agreement (Landis & Koch, 1977).

4.3 Results

The level of intra-rater agreement for scoring the passing criteria was substantial to almost perfect (κ = 0.62-0.99) for each test. The level of intra-rater agreement for scoring the tackle skill criteria was almost perfect (κ = 0.87-0.99) for each tackle test. There was a significant effect of developmental level for the passing assessment (V = 0.303, F = 2.406, P<0.05) with the SL group performing at a superior capacity relative to their U20 and U18 counterparts for accuracy at 4m, (*d*=0.65 and *d*=0.19, respectively), 7m (*d*=0.77 and *d*=0.51, respectively) and 12m (*d*=1.05 and *d*=0.81, respectively). For left-to-right passes, the SL group demonstrated greater accuracy with trivial effect sizes between groups for all three distances: 4m, 7m, and 12m (Table 5). There were little differences between developmental level for ball flight time for 4m left-to-right, and 7m right-to-left; however, the SL group had significantly greater scores and legal passes compared to the U18 and U20 groups over these distances. Conversely, the SL group score, ball flight time and legal pass frequency for 12m left-to-right (ball flight *d*=11.44 and accuracy *d*=0.54) and right-to-left (ball flight *d*=0.52 and accuracy *d*=0.64) were significantly better compared to the U20 group (Table 5).

Given the significant passing results from the MANOVA, ROC curves were developed to identify the variables expressing the greatest between-group discrimination. Figure 12A demonstrates a 'cut-off' score for the 4m left-to-right pass for U18 was 5.2au (from a possible 6au) with the AUC being 74.5%, discriminating 66.6% of U18 from the SL.

Table 5. Between group effects for rugby league specific passing assessments.

Variables	**U18**	**U20**	**SL**	**U18 – U20** *d*	**U18 – SL** *d*	**U20 – SL** *d*
Mean score (maximum six arbitrary units)						
4m left-to-right	4.5 ± 1.3 [a]	4.6 ± 1.9 [a]	5.6 ± 1.2	0.08	0.91	0.65
4m right-to-left	4.8 ± 1.7 [a]	4.4 ± 1.7 [a]	5.6 ± 1.0	0.00	-0.01	-0.01
7m left-to-right	3.1 ± 2.1 [a]	2.9 ±1.9 [a]	4.7 ± 1.3	-0.19	0.51	0.77
7m right-to-left	1.9 ± 1.6 [a]	2.6 ± 1.8 [a]	3.8 ± 1.9	0.02	-0.01	-0.03
12m left-to-right	1.6 ± 1.7	1.3 ± 1.3 [a]	2.3 ± 2.2	-0.18	0.81	1.05
12m right-to-left	0.7 ± 1.1 [a]	0.9 ± 1.4 [a]	1.9 ± 1.8	0.03	-0.01	-0.03
Mean time (seconds)						
4m left-to-right	0.47 ± 0.1	0.48 ± 0.1	0.46 ± 0.0	7.00	21.96	25.60
4m right-to-left	0.47 ± 0.0	0.49 ± 0.1 [a]	0.45 ± 0.1	-0.11	-0.46	-0.33
7m left-to-right	0.67 ± 0.1	0.71 ± 0.1 [a b]	0.66 ± 0.1	-3.50	7.26	11.78
7m right-to-left	0.69 ± 0.1	0.68 ± 0.1	0.66 ± 0.1	-0.40	-0.99	-0.71
12m left-to-right	1.12 ± 0.2 [a]	1.08 ± 0.1	1.04 ± 0.1	1.55	8.79	11.44
12m right-to-left	1.05 ± 0.1 [a]	1.06 ± 0.1 [a]	0.98 ± 0.1	0.10	-0.56	-0.52
Legal pass completed	%	%	%			
4m left-to-right	83.9 ± 21.5	83.9 ± 24.6 [a]	94.8 ± 17.2	0.00	-0.56	0.52
4m right-to-left	87.6 ± 21.0	83.9 ± 22.9 [a]	96.9 ± 13.0	0.17	-0.54	0.72
7m left-to-right	61.7 ± 35.5 [a]	58.6 ± 31.7 [a]	81.2 ± 25.3	0.09	-0.64	0.79
7m right-to-left	43.2 ± 31.8 [a]	54.0 ± 36.1	69.8 ± 28.6	-0.32	-0.88	0.49
12m left-to-right	46.9 ± 26.6	37.9 ± 31.8 [a]	57.3 ± 39.9	0.31	-0.31	0.54
12m right-to-left	14.8 ± 23.2 [a]	21.8 ± 25.6 [a]	39.6 ± 29.8	-0.29	-0.93	0.64

[a] significantly ($P<0.05$) different to SL, [b] significantly ($P<0.05$) different to U18, *d* effect size. Forward passes received a 0 score.

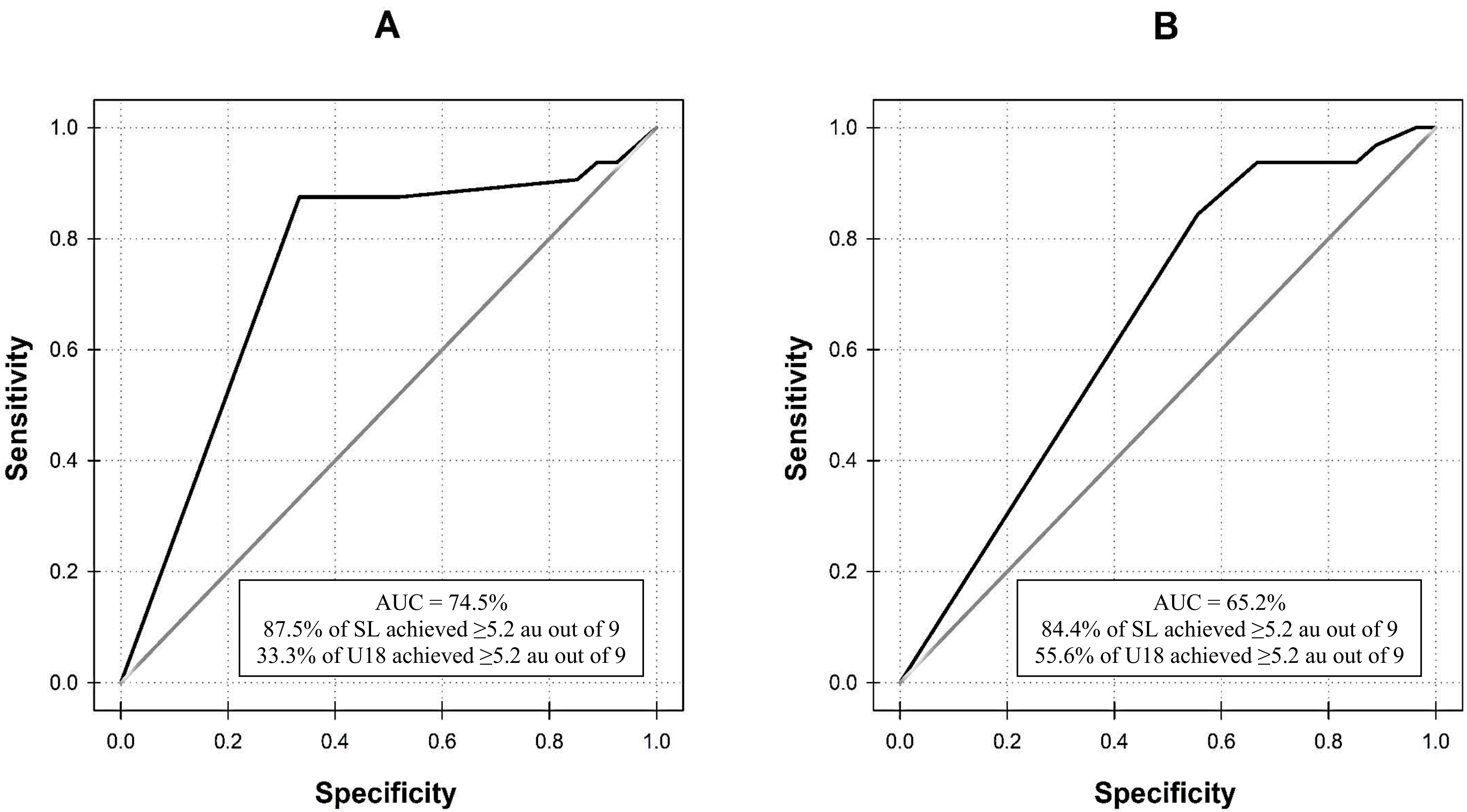

Figure 12. ROC curves showing the point generating the greatest AUC discriminating the U18 to the SL for: **A)** 4m left-to-right pass score; **B)** 4m right-to-left pass score.

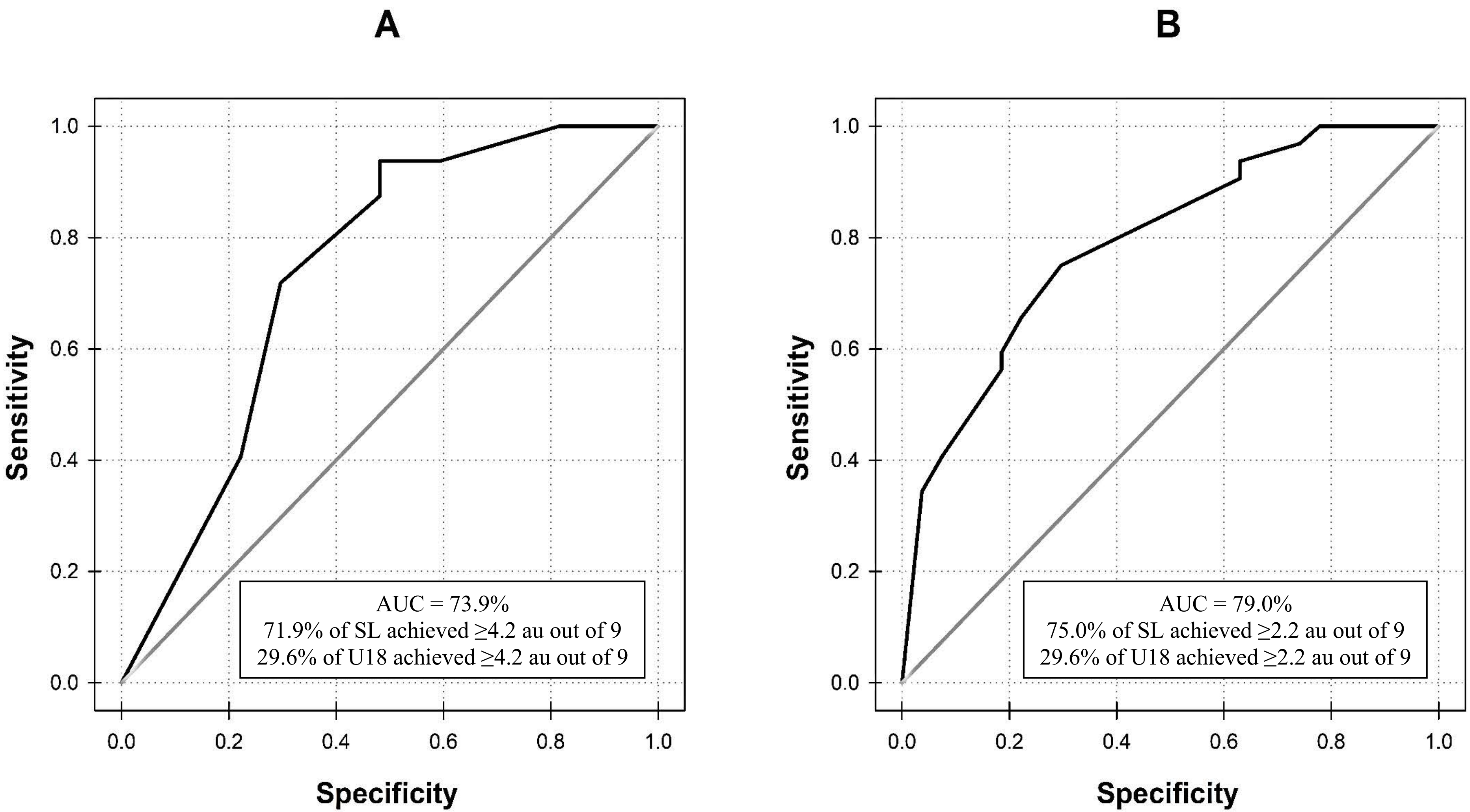

Figure 13. ROC curves showing the point generating the greatest AUC discriminating the U18 to the SL for: **A)** 7m left-to-right pass score; **B)** 7m right-to-left pass score.

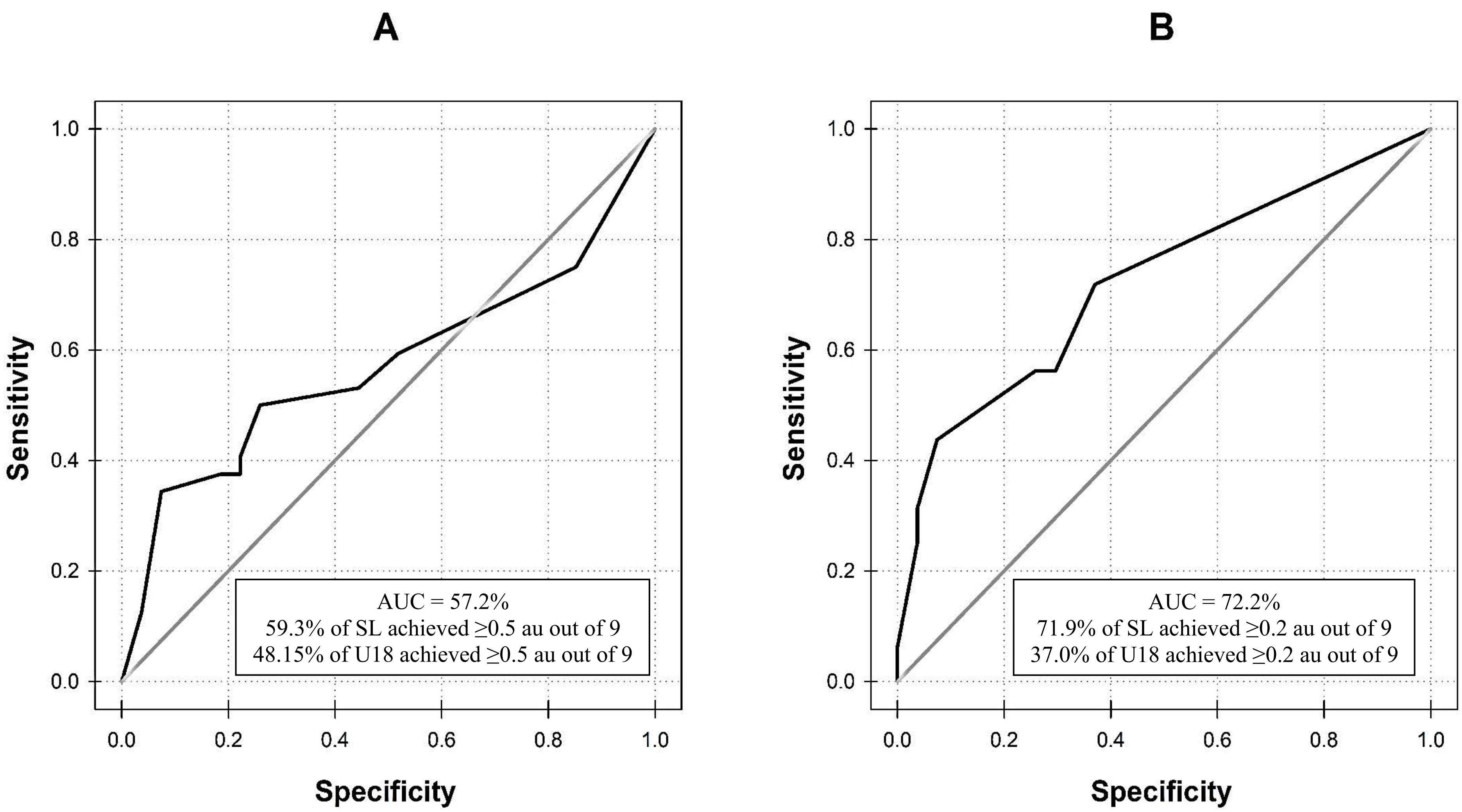

Figure 14. ROC curves showing the point generating the greatest AUC discriminating the U18 to the SL for: **A)** 12m left-to-right pass score; **B)** 12m right-to-left pass score.

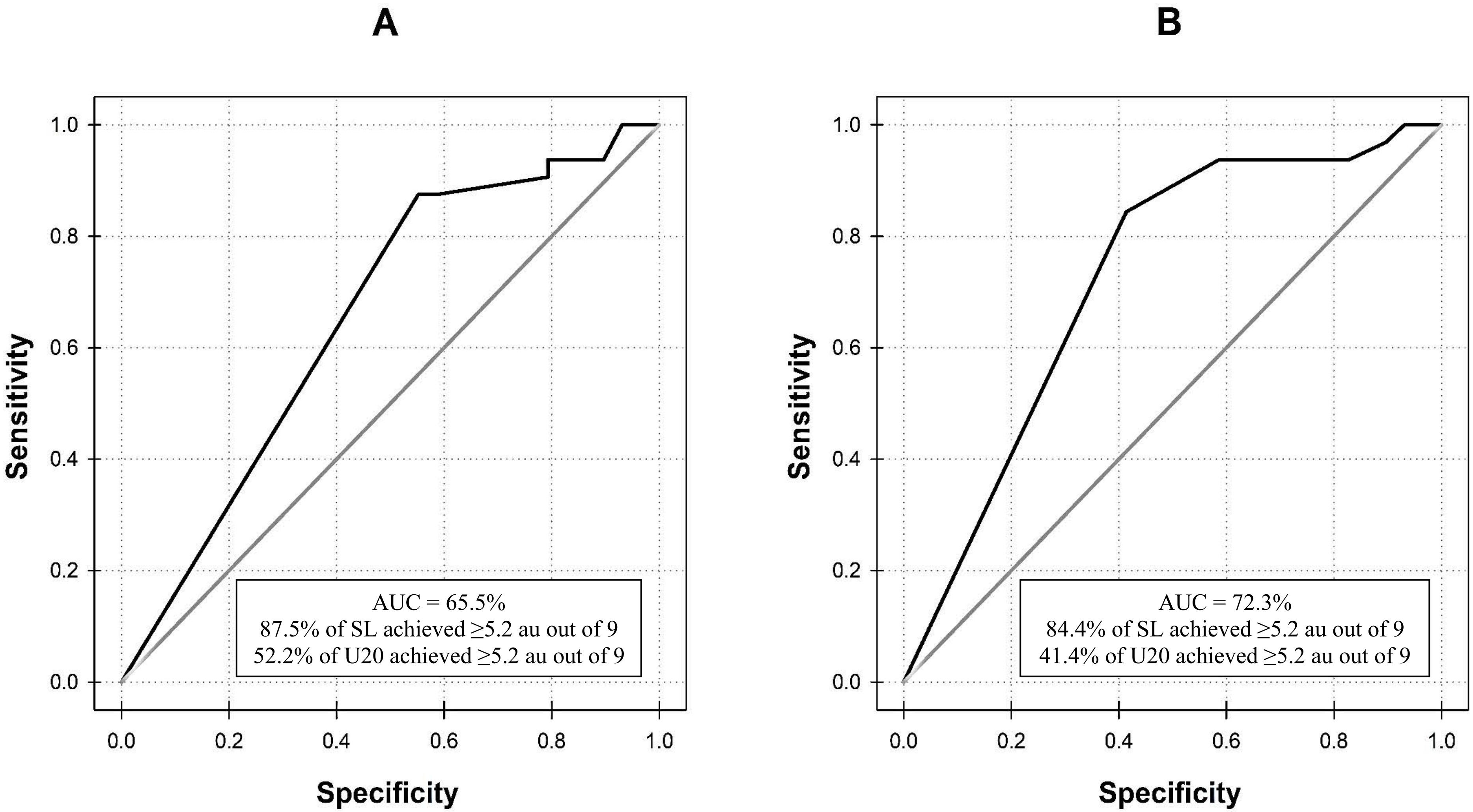

Figure 15. ROC curves showing the point generating the greatest AUC discriminating the U20 to the SL for: **A)** 4m left-to-right pass score; **B)** 4m right-to-left pass score.

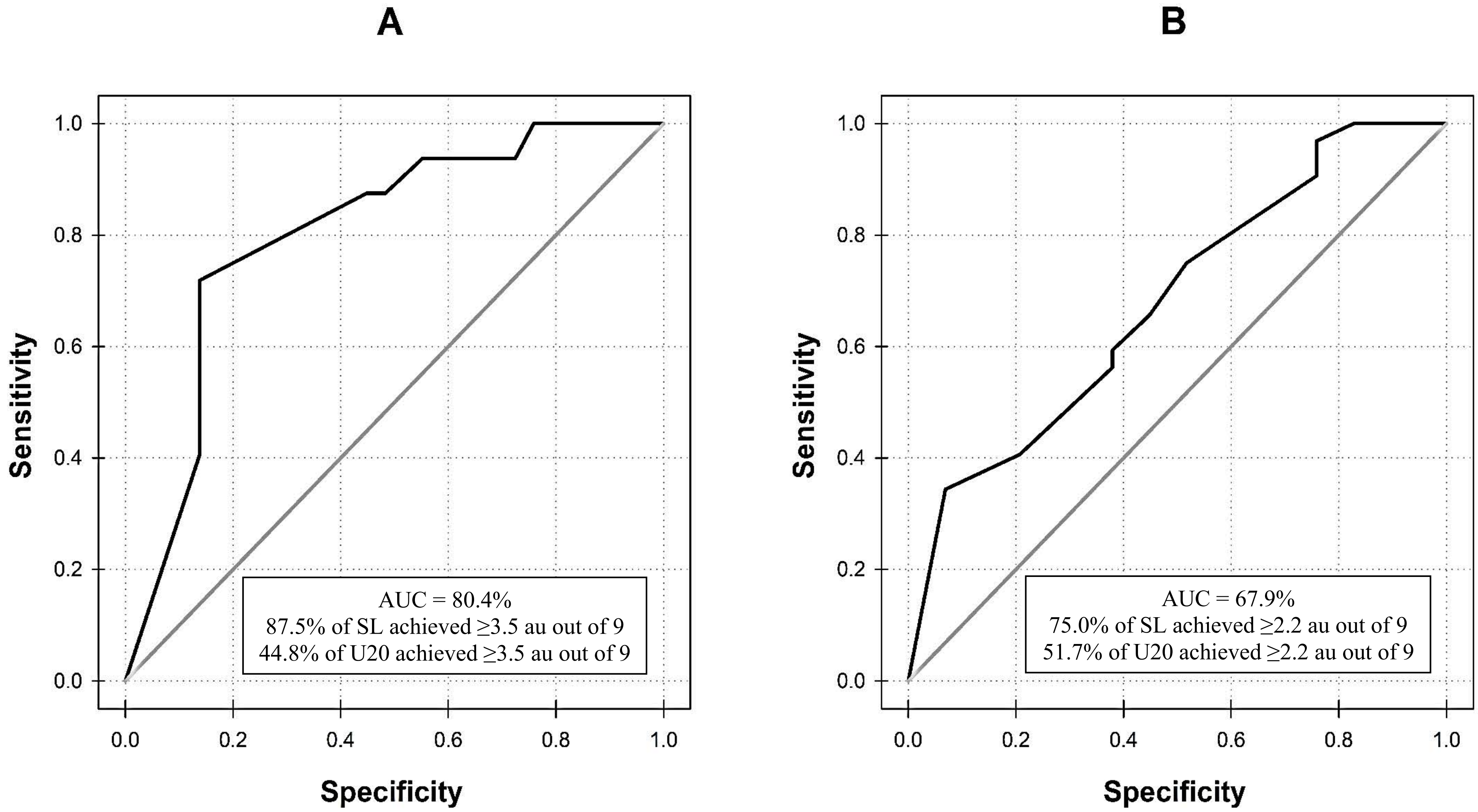

Figure 16. ROC curves showing the point generating the greatest AUC discriminating the U20 to the SL for: **A)** 7m left-to-right pass score; **B)** 7m right-to-left pass score.

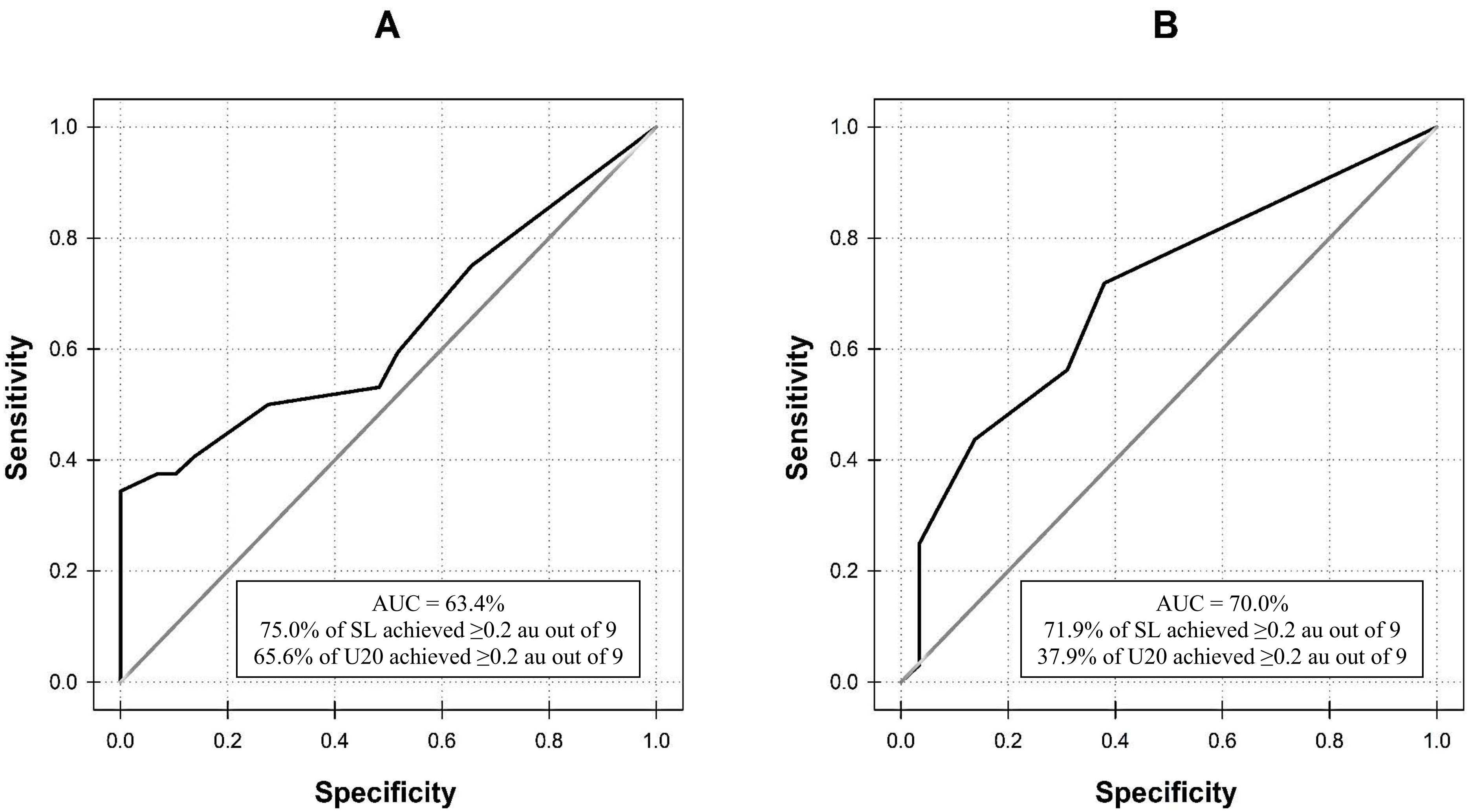

Figure 17. ROC curves showing the point generating the greatest AUC discriminating the U20 to the SL for: **A)** 12m left-to-right pass score; **B)** 12m right-to-left pass score.

Cross tabulation of tackle mode frequency revealed that the SL group were likely to perform a right shoulder 'ball and all' tackle compared to U20 and U18 groups (χ^2 *(1,* N = 93) = 86.19, P<0.05). Further, the U20 and U18 groups appeared more likely to perform right shoulder, 'leg drive' tackles compared to the SL group (χ^2*(1,* N = 149) = 86.19, P<0.05 (Table 6).

The front-on tackle choices observed were 'ball and all' (total of 132 from 192 trials for SL, and 14 from a potential 174 trials and 36 from a potential 162 trials for juniors); 'leg drive' (total of 46 for SL, and 136 and 117 for U20 and U18 respectively); and the 'block' tackle (two observations for SL, and six and three for U20 and U18, respectively). For left and right shoulder tackles, significant relationships between developmental level and tackle choice were identified with SL more likely to execute 'ball and all' tackles compared to the U20 and U18 groups (χ^2*(1,* N = 93) = 84.36, P<0.05) and the U20 and U18 groups more likely to execute 'leg drive' tackles compared to the SL group (χ^2*(1,* N = 149) = 84.36, P<0.05; Table 6).

Table 6. Between group effects for rugby league specific tackling assessments

Variables	**U18**	**U20**	**SL**	**U18 – U20 *d***	**U18 – SL *d***	**U20 – SL *d***
Mean score criteria achieved (expressed as a percentage)						
Block tackle right shoulder	87.5	87.5 ± 17.7	100.0			
Leg drive tackle right shoulder	74.3 ± 19.3	82.0 ± 13.0	78.4 ± 19.9 [ab]	0.47	0.21	-0.22
Ball and all tackle right shoulder	72.8 ± 18.8	60.0 ± 6.1	78.1 ± 18.5 [b]	-1.03	0.28	1.47
Block tackle left shoulder	68.8 ± 2.5	93.8 ± 12.5	87.5		3.33	
Leg drive tackle left shoulder	79.5 ± 14.9	80.0. ± 16.4 [a]	88.0 ± 9.0	0.03	0.71	0.64
Ball and all tackle left shoulder	70.7 ± 14.4	53.3 ± 14 [a]	76.1 ± 16.9 [b]	-1.20	0.34	1.45
Relationship between competition and tackle choice (cross-tabulation expressed as a percentage)						
Block tackle right shoulder	2.5*	5.0*	1.1*			
Leg drive tackle right shoulder	74.7	85.0	24.4			
Ball and all tackle right shoulder	22.8	10.0	74.4			
Block tackle left shoulder	2.6*	5.1*	1.1*			
Leg drive tackle left shoulder	74.4	87.2	26.7			
Ball and all tackle left shoulder	23.1	7.7	72.2			

[a] significantly (P<0.05) different to U18, [b] significantly (P<0.05) different to U20, *d* effect size.
If no standard deviation is presented then group had fewer than two observations, *expected count in Chi-square tests less than five observations, expected minimum count is 2.2.

4.4 Discussion

This chapter compared passing and tackling between developmental levels within the Qld RLTP and contributed to the existing literature on technical skills in RL. Results showed that the SL group exhibited superior passing and tackling qualities compared to their junior counterparts. Passing ability for distances at 4m, 7m, and 12m, and tackle ability for 'ball and all' and 'leg drive' tackles discriminated the SL group from the U18 and U20. For brevity, the discussion of this chapter is split into passing and tackling assessment sections.

4.4.1 Passing Assessment

The accuracy of the pass, the ball flight speed and the legality of the pass were determined. For distances greater than 7m, we noted faster ball flight times resulted in decreased accuracy and greater number of forward pass for all groups. These results were likely due to an increase in task difficulty (with the target being further away). However, the SL group performed better compared to the U18 and U20 groups, which may be due to a more developed skill associated with longevity of experience (Miller et al., 2016) and better physical qualities such as power production and athletic movement ability (as shown in Chapter 3).

Despite similar speed of ball flight within groups for left-to-right and right-to-left passes, the accuracy for the right-to-left pass was compromised for all three groups (Table 5), which may indicate players have a preferred passing side. The preferred side may be related to their dominant side or handedness (Pavely, Adams, Di Francesco, Larkham, & Maher, 2009). For example, semi-elite rugby union players passing from the non-dominant side were reported to produce a greater frequency of forward passes compared to the dominant (preferred) passing side (57% and 15%, respectively) (Pavely et al., 2009).

4.4.2 Tackling Assessment

Excluding the block tackle due to minimal observations, the SL group demonstrated greater proficiency in left and right shoulder 'leg drive' tackles and left shoulder 'ball and all' tackles compared to junior counterparts. Both SL and U18 achieved significantly greater results for right shoulder 'ball and all' tackle compared to the U20 group.

The 'ball and all' tackle was the prominent tackle type used by the SL group (Table 6), likely due to a decreased risk of ball off-load (pass during tackle effort) (Gabbett & Kelly, 2007). However, the 'ball and all' tackle has an increased risk of incurring a missed tackle (Speranza et al., 2017). This risk may be offset by including two or more defenders in each tackle effort, commonly observed in senior competition, wherein accessory defenders contact the ball-carrier at lower body positions to impede forward movement (Gabbett & Kelly, 2007).

The U18 and U20 groups executed the 'leg drive' tackle more often compared to the 'ball and all' tackle during the assessment. The 'leg drive' tackle is a primary defensive skill taught in junior RL for one versus one tackling (Corcoran et al., 2000). The U18 and U20 group's familiarity with the 'leg drive' tackle may have underpinned confidence to execute this front-on tackle type more frequently during assessment. Despite the difference of tackle type between all three groups, and the less than expected passing accuracy and symmetrical ability from the SL group, the SL group were significantly more proficient when compared with the U18 and U20 groups. Developmental level proficiency for technical skill performances may be positively correlated with age (Wilson et al., 2016), greater competition experience (Miller et al., 2016), and extended exposure to quality coaching (Woods et al., 2016c).

Despite the practical implications of this research, it is important to acknowledge its limitations. Firstly, the tests used were more static than would be observed during game play, as they did not allow for adaptability of movement based upon the constraints that shape typical RL task performance. Also, RL is a multidimensional sport, requiring physical, technical, and tactical performance qualities, and the current chapter only compared the fundamental technical performance of RL players at different stages within the RLTP with physical (Chapter 3) and tactical (Chapter 5) aspects addressed elsewhere in this thesis.

In conclusion, this chapter highlighted the fundamental technical skill differences between developmental levels for players within the Qld RLTP. Most apparent were passing distances greater than 4m, tackle choice and tackle skill. These technical differences may be due to SL having experienced greater exposure to qualified RL coaches for skill acquisition and having greater competition experience, compared to the junior levels (Gabbett, 2002; Vandervoort, 2002). Superior attacking and defensive play qualities such as passing and tackling is a critical component of successful game play (Gabbett & Hulin, 2018), it makes sense the RLTP should emphasise pronounced development of these fundamental technical skill for competitive junior to senior transition.

Chapter 5 Type and Variation of Evasive Manoeuvres During an Attack Task Differ Across a Rugby League Developmental Pathway

Author Contributions

L.A.P. contributed 75% to this chapter. She developed the chapter structure, wrote each section, collected and analysed the data. C.T.W., A.S.L. and W.H.S. offered conceptual guidance and statistical support where required (20%), while M.A.G. assisted with the statistical analyses (5%).

5.1 Introduction

In addition to the physical (Chapter 3) and technical skills (Chapter 4) previously discussed, RL game play requires players to make a range of tactical decisions in an attempt to exploit their opponents positioning whether in attack or defence (Johnston et al., 2014). In Australia, state-based organisations act as the primary feeder for the premier RL competition, the NRL. Within these feeder competitions, such as the Qld Cup, there are established developmental pathways that intend to augment the development of talented RL players (which has been described in detail throughout Chapters 1-4 of this thesis). Therefore, it would be important for their practice designs to be informed by an evidence-based approach (Cobley & Till, 2015; Ireton et al., 2017; Pearce et al., 2018; Pearce, Sinclair, Leicht, & Woods, 2019).

Relative to research conducted on the physical and technical aspects of RL (i.e., Chapters 3 and 4 of this thesis), there has been limited research examining the decision-making skill of players across a talent pathway. Indeed, some research has suggested that elite RL players have a reduced attentional demand compared to sub-elite counterparts during a field-based draw-and-pass test (Gabbett et al., 2011c). Notably, elite players showed a smaller performance decrement during a dual-task activity relative to their sub-elite peers (Gabbett & Abernethy, 2012; Gabbett et al., 2011c). The importance of decision-making during competition was further highlighted by Gabbett and Abernethy (2012) who noted that approximately 50% of tries scored in the NRL resulted from the successful execution of a deceptive or evasive action (i.e., movements that coerce an opponent into a movement pattern that is then exploited by the ball carrier).

In RL, evasive actions are typically utilised with the intention of deceiving an opponent to gain territory or increase the opportunity to rapidly continue game play after a tackle. Additionally, evasive manoeuvres may be implemented to draw and commit a defender towards the ball carrier, increasing the opportunity for any supporting players to receive an unimpeded pass (Australian Rugby League Commission, 2015). Both scenarios (evasion or draw and pass) increase the potential of inducing a line-break, which may result in the attacking team gaining territory downfield or ideally, scoring a try (Australian Rugby League Commission, 2015). Subsequently, the development of evasive skill may lead to greater success in RL and should be a critical focus for the development of talented RL athletes (Cupples & O'Connor, 2011).

This chapter sought to examine whether evasive decision-making skills measured via an attack task differentiated developmental level in the Qld RLTP. Based on the findings presented in Chapters 3 and 4 of the thesis, it was hypothesised that the type and variety of evasive manoeuvres used in this task would differ according to developmental level.

5.2 Methodology

5.2.1 Experimental Approach to the Problem

This chapter followed an observational, cross-sectional research design with data collected during the early competition phase of the season to standardise training related adaptations and elementary components of training. All participants undertook a field-based attack task which was modified from prior research of a draw-and-pass test (Gabbett & Abernethy, 2012; Gabbett et al., 2011b; Gabbett et al., 2011c). The reliability of the draw-and-pass performance test was reported to be good, with an intraclass correlation coefficient and typical error of measurement of 0.86 and 0.80 arbitrary units (coefficient of variation = 2.7%) (Gabbett & Abernethy, 2012).

5.2.2 Participants

The total sample consisted of 90 male participants from five RL clubs competing in the same state-based competition. Each participant was categorised according to their developmental level; U18 (n = 30), U20 (n = 30) and SL (n = 30). Playing position was considered with an equal number of each position (i.e., forwards and backs) being included in each developmental group. Ethical approval was granted from the relevant human research ethics committee (approval H7685) and all participants and / or guardians (for the U18 participants) provided written informed consent.

5.2.3 Procedures

The task consisted of three attackers versus two defenders completing a draw and pass attack. A schematic of the task's design is presented in Figure 18. The participant starting the task in the attacker 2 position (A2; Figure 18) was the one assessed during the trial. The task was conducted within a 15 x 11m area on a standard RL field. Two standard, two-dimensional, video cameras (Sony CX405 Full HD Handycam, Singapore) were positioned 8m behind and 6m perpendicular to the task and recorded each trial for later analysis (Figure 18). Pilot work revealed that these camera perspectives afforded optimal viewing for the task.

In accord with the task descriptions of Gabbett et al. (2011c), the task design represented an attacking play sequence following a tackle. As shown in Figure 18, each participant completed three trials in the A2 starting position and self-selected their starting position on the 0m line between their two support players (A1 and A3). Participants were from the same development level and included two defenders (DL, DR) who commenced at the 8m line facing the attacking participants A1-A3 (Figure 18). Participants A1-A3 were instructed to execute attacking manoeuvres to elicit the desired outcome of a line-break and to complete the task at game speed to progress the ball 1m beyond the 10m line. The location of the starting position for player A2 was recorded as either opposite DL, opposite DR or evenly spaced between defenders (Table 7).

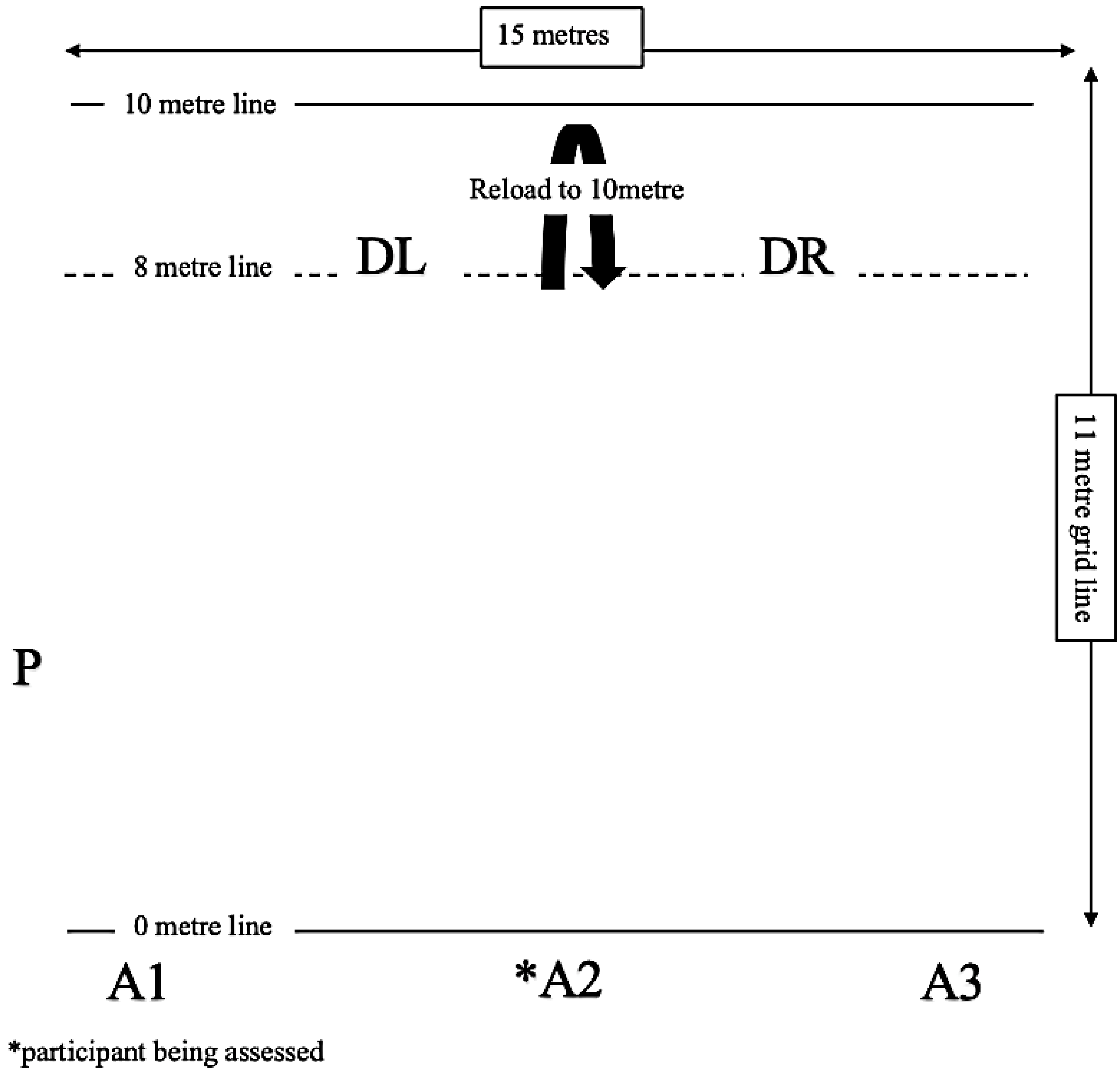

Figure 18. 3-v-2 attack assessment task field set up.

DL=defender left; DR=defender right; P=participant executing initial pass; A1=attack player 1; *A2=attack player 2 and the participant being observed; A3=attack player 3.

Table 7. The evasive manoeuvres and subsequent definitions as used in the attack play task.

Evasive Manoeuvre	**Definition**	
Skip	Change of tempo (slow to fast). Permits maintenance of balance to affect rapid change of direction	
Step	A shortened stride to a wide step off the outside leg. Weight is shifted to other leg to accelerate from standing foot	
Change of direction	Change direction of current line	
Start Square	Shoulder and hips face forward to initiate task run	
Square up	Straightening shoulder and hips to face forward after initial angle run	
Angle run	Run diagonally from pass receipt	
Run angle left, pass left	Angle run to left and pass ball to left	
Run angle left, pass right	Angle run to left and pass ball to right	
Dummy pass	Deceiving opposition with fake pass or direction of pass	
All square run	Shoulder and hips facing forward, running forward straight line	
Run angle right, pass left	Angle run to right and pass ball to left	
Run angle right, pass right	Angle run to right and pass ball to right	
Behind flick pass	The ball is passed with a flick of the wrist behind ball carrier's torso	
Combination	Two or more of the above manoeuvres executed in trial	
Start Position		
Opposite defender left	Participant positions opposite the left defender	
Opposite defender right	Participant positions opposite the right defender	
Middle position	Participant positions evenly spaced between defenders	
Outcome Score		**Score**
Evaded tackle	Linebreak completed. Increased opportunity for territory or try scoring.	5
Tackled by one defender	One defender completed two handed touch (tackle). Attack not slowed, and ball is maintained	3
Tackled by two defenders	Both defenders completed two handed touch (tackle). Attack is slowed and ball is maintained	1
Lost possession	Illegal (forward) pass, or play would result in loss of ball possession	0

The task commenced with a left-to-right pass (from P) to the participant (A2). In this task, the defenders started within 2m of the 10m distance and were instructed to re-load (back up to the 10m line) and then attempt to defend against the attacking play. Upon receipt of the pass, A2 attempted to advance the ball using any legal means possible to evade defenders or draw defenders, thereby enabling A1 or A3 to successfully perform a line-break. The defenders were instructed to defend the attacking play and effect a tackle as simulated via a two-handed touch of the ball carrier. The starting position, type of evasive manoeuvre and outcome of task undertaken by player A2 were recorded. Type of evasive manoeuvre was categorised using defined criteria modified from previous research (Gabbett & Abernethy, 2012; Gabbett et al., 2011c), with their definitions also being informed in conjunction with an NRL Level 3 and RL talent development coach, sport scientist and a skill acquisition specialist (Table 7).

5.2.4 Statistical Analysis

All analyses were conducted using SPSS version 25 (IBM. Corp., Armonk, NY). Relationships between the developmental level and evasive manoeuvres, based on frequencies, were determined using the Fischer's Chi-square test (Crosstabs Command) with adjusted residuals (AR) >1.96 classified as significant, and Cramer's V test used to represent the magnitude of difference or effect size (ES). Logistical regression was conducted to identify associations between the response variable (developmental level) and the explanatory variables including start position, evasive manoeuvre and task outcome score (statistical significance $P \leq 0.05$).

5.3 Results

The outcome score for the task did not significantly differ between development levels (U18, 4.0 ± 1.8; U20, 4.0 ± 1.7; SL, 4.3 ± 1.5). However, the relationship between development level and evasive manoeuvres was significant ($\chi^2 = 35.916$; $df = 26$; $P = 0.026$; ES = 0.27). For the

U18 level, more participants completed a 'square up' move (AR=2.2) and less completed a combination of evasive manoeuvres (AR=-2.4) compared to the U20 and SL levels (Table 8). For the U20 level, more participants completed an 'all square run' (AR=2.0) compared to the other development levels (Table 8). The SL participants recorded a greater frequency of 'angled run' (AR=2.2), 'all square run' (AR=2.0) and combination of evasive manoeuvres (AR=2.5) compared to the other levels (Table 8). The SL level started the task from the right more (AR=3.8) and less from the middle positions (AR=-2.1) compared to the U18 and U20 development levels.

The logistical regression model for development level was significant (Likelihood Ratio Tests = 363.131, $\chi^2 = 102.740$; $df = 58$; $P<0.001$) with a classification accuracy of 58.9% (Nagelkerke $R^2 = 0.356$). The significant predictors of developmental level were starting position and outcome score. Specifically, there was a greater probability that U18 (odds ratio $=6.5 \times 10^{-7}$, $P<0.05$) and SL (odds ratio $= 2.1 \times 10^{7}$, $P<0.05$) participants would commence the task from the left position compared to U20 participants. In addition, SL participants had a greater probability of performing 'step' (odds ratio = 9.667; $P<0.05$), 'square up' (odds ratio = 7.672; $P<0.05$) and 'all square' runs (odds ratio = 3.317; $P<0.05$) compared to the U18 level.

Table 8. Frequency (%) of starting position and evasive manoeuvres undertaken by under 18, under 20 and State League players during the 3-v-2 attack task.

Start Position	**U18 (%)**	**U20 (%)**	**SL (%)**
Opposite defender left	11.1	6.7	10.0
Between defenders	88.9	93.3	82.2[ab]
Opposite defender right	0.0	0.0	7.8[ab]
Evasive Manoeuvre			
Skip	0.0	0.0	3.3
Step	13.3	20.0	14.4
Change of direction	21.2	22.2	20.0
Start square	1.1	5.6	8.9
Square up	8.9	5.6[a]	6.7[a]
Angle run	3.3	5.6	10.0[ab]
Run angle left, pass left	5.6	2.2	5.6
Run angle left, pass right	1.1	0.0	4.4
Dummy pass	20.0	21.1	22.2
All square run	35.6	38.9	27.8[ab]
Run angle right, pass left	0.0	1.1	4.4
Run angle right, pass right	2.2	0.0	1.1
Behind flick pass	0.0	1.1	3.3
Combination of manoeuvres	12.2	20.0	28.9[ab]

[a]$P<0.05$ vs U18; [b]$P<0.05$ vs U20.

5.4 Discussion

This study examined whether evasive decision-making skill, measured via an attack play task, differentiated developmental level in the Qld RLTP. Results indicated that the task outcome scores were consistent across the three development levels. However, differences in the type and variety of evasive manoeuvres used in addition to players starting positions were identified between developmental levels. Interestingly, the U18 and U20 levels adopted similar evasive manoeuvres, with significant differences being found between these levels and the SL level.

The general theme of these results is consistent with those observed in Chapters 3 and 4, with the U18 and U20 levels obtaining similar performance qualities, but both yielding significant differences to the SL level.

With a specific focus on the results of this chapter, the SL players performed a range of intentional evasive manoeuvres and appeared to deliberately position themselves opposite one particular defender (DR) at the initiation of the attacking task relative to the U18 and U20 levels. This suggests that the SL participants may have engaged in a pre-emptive strategy (starting position manipulation) that they perceived would increase their likelihood of achieving the task goal (e.g. to score). This could be indicative of greater knowledge of their performance environment relative to the younger developmental levels, developed over prolonged exposure to rich and diverse practice designs (Davids, Araújo, Seifert, & Orth, 2015). Further, the SL participants were more likely to use a variety of evasive manoeuvres throughout the task to draw and commit the defender to the ball carrier, increasing the opportunity to create a line-break (Australian Rugby League Commission, 2015). The increased combinations of evasive manoeuvres further suggests SL participants were able to interpret defensive movements and then readjust their attacking movements to increase their chances of achieving the task goal. For example, the ball carrier could accelerate and adjust their speed in accordance with the drawn defender to deceive them into altering their momentum with the intention to unbalance the defender (wrong-foot). The ball carrier could then exploit this by evading their defender through changing direction and stepping back toward the origin of the pass, further drawing the defender from the defensive line to allow a supporting attacking player to run into the hole created in the defensive line.

As mentioned previously, the starting position for the U18 and U20 players was similar with players positioning themselves between both defenders with a slightly closer proximity to DL. This indicates a potential lack of knowledge of their performance environment relative to their SL peers, being unable to recognise opportunities in their environment of assistance to evade their defender prior to task initiation. Thus, coaches of younger developmental levels could implement learning designs that encourage players to explore differing start positions and evasive manoeuvres when performing tasks like those used here. Further, coaches could use questioning to educate a players attention toward critical features of their environment that may assist their capability to detect and exploit the positioning of defenders (Chow et al., 2007). Conceivably, the apparent performances of the SL participants may be merited to experience gained from greater competition exposure when compared to the U18 and U20 levels (Lavie, Hirst, De Fockert, & Viding, 2004). Conceivably, the SL players have learned they can achieve effective results with combinations of movements performed during the task. For example, they square up once they detect their defenders are wrong footed or when they perceive they have an advantage such as a capability to accelerate past their defender. Further the longevity of exposure to competition likely developed and enhanced their selective attention capacity (Lavie et al., 2004), affording the player opportunities to detect relevant information in their environment, attuning to more evasive opportunities (Murphy, Groeger, & Greene, 2016).

The SL participants demonstrated greater variability in start position and combination of evasive manoeuvres when completing the task. The results of this chapter may be of use for talent development in the U18 and U20 levels, emphasising the importance of structuring practice tasks at these younger levels to afford players the freedom to explore evasive manoeuvres. It is likely that their knowledge of the game will develop, increasing their capacity to detect relevant opportunities to evade a defender, augmenting the junior-to-senior transition.

Chapter 6 Thesis Summary, Conclusions and Future Research Directions

6.1 Summary

The aim of the thesis was to identify the physical, technical, and tactical performance qualities that discriminate developmental level in the Qld RLTP. The main findings were the similarities in most performance qualities noted between the U18 and U20 developmental levels, and the large deficit between these levels and the SL. Accordingly, the following sections of this chapter will summarise these findings by focusing on the main results from each study.

6.1.1 Chapter 3 – The Physical

Chapter 3 investigated the physical, anthropometric, and athletic movement qualities that discriminated developmental level in the Qld RLTP. The main findings to stem from this chapter were the similarities in the performance qualities between the U18 and U20 levels, and the large gap between these levels and the SL. Most notably, the SL participants were heavier and produced a greater peak and average power output compared to U18 and U20 participants. Discrimination measured using ROC curves demonstrated that over 60% of the SL participants had a body mass of 85.5kg or greater compared to only ~31% of U18 / U20 participants combined. Further, 65% of the SL participants generated a lower limb power of >3040W, compared to only 30% of U18 / U20 participants combined.

In addition to these physical and anthropometric differences, the SL participants possessed a greater athletic movement competency relative to the U18 and U20 levels. Notably, 78% of the SL participants achieved a score of greater than 39.5au (maximum of 54au) compared to only 21% of the U18 / U20 participants when performing the AAA. These findings were explained relative to the exposure to intentional strength coaching with the SL participants likely being exposed to prolonged strength training within the RLTP when compared to players at the U18 and U20 levels (Miller et al., 2016). Combined, these results suggest that both power generation and athletic movement competency should be prioritised earlier within the Qld RLTP. Discussed in greater detail in Chapter 7, the integration of professional strength and conditioning coaches within the junior ranks (i.e., less than 20 years of age) that have a specific focus on the development of athletic movement competency may minimise the apparent physical performance gaps noted in this chapter, thereby assisting with talent development.

6.1.2 Chapter 4 – The Technical

Chapter 4 examined the discriminative capability of passing and tackling assessments across the Qld RLTP. Like Chapter 3, results demonstrated similarities between the U18 and U20 levels, and a large gap between these levels and the SL. Regarding the passing task, the SL participants were significantly more accurate compared to both the U18 and U20 levels, likely due to greater playing and training experience (Miller et al., 2016). Interestingly, regardless of developmental level, decrements in accuracy, coupled with an increased frequency of illegal passes, were noted for right-to-left passes over distances greater than 4m. This indicated a potential dominant side for passing by all participants, which could limit the number of passing options for players, decreasing offensive opportunities during game play.

A similar finding was observed in the tackling assessment, with the U18 and U20 levels showing similar qualities relative to the SL level. Notably, the U18 and U20 participants preferred to perform a leg drive tackle for both left and right shoulder tackles, while the SL participants had a greater frequency of ball and all tackles for both shoulder tackles. In addition to the different tackle preferences, significantly superior tackle performance was demonstrated by SL participants compared to U18 and U20 participants. Combined, the results from this chapter uncovered a gap for both passing and tackling skills between the U18 / U20 levels and the SL level, with the practical implications of these results discussed in Chapter 7.

6.1.3 Chapter 5 – The Tactical

Chapter 5 assessed the decision-making skill of the participants during an attack play task, using it to quantify starting position and evasive manoeuvres when in possession of the ball. Again, the results presented a similar theme to Chapters 3 and 4, with the U18 and U20 levels showing similar performance attributes but contrasting the SL participants. Specifically, the results demonstrated differences in both starting position and evasive manoeuvre between the SL participants and the U18 and U20 levels. Of note, the SL participants positioned themselves opposite a defender at the start of the task in what appeared to be an intentional act of drawing attention in order to create space for a support player to receive and run with the ball. This contrasted with both the U18 and U20 levels, who did not manipulate their start position in such a strategic way.

In addition to the starting position, the SL participants performed a greater number of combined evasive manoeuvres including the angled run when compared to U18 and U20 participants. These findings suggest that the intentional start position combined with the angled run choice may have created more space for the SL players to perform additional evasive actions compared to their younger peers. These findings were discussed relative to the exposure to training environments and competition with the SL participants likely to have had access to high-quality coaching and developmental opportunities relative to the U18 and U20 levels. Accordingly, skilled development coaches may incorporate problem-solving tasks, including the creation of space, at earlier stages of the RLTP in Qld.

6.2 General Conclusions and Future Research Directions

Collectively, these three research chapters identified several performance qualities, categorised into physical, technical, and tactical components, that discriminated RL players at different stages of the talent pathway in Qld. Importantly, differences between the U18 and U20 participants were minimal, with only one component of movement competency in Chapter 3 and four technical aspects in Chapter 4 being identified as significantly different between these levels. In contrast, large gaps in physical, technical, and tactical qualities between the combined U18 / U20 participants and the SL participants were identified throughout Chapters 3, 4 and 5. These large and disproportionate gaps in the RLTP suggest a review of the current pathway structure (including resources) would be warranted. I discuss this proposed pathway restructure in Chapter 7, but the findings in this thesis should provide the Qld RLTP with a more meaningful, and evidence-based process by which talent could be fostered and developed. Further, the findings of this thesis have paved the way for future research directions, some of which are discussed in greater detail below.

Firstly, given this thesis identified disproportionate gaps between the U18, U20 and SL levels, future research should look to extend to the examination of performance differences between players at earlier and later stages of the talent pathway. For example, future research could look to examine the performance gaps between the U14 and U16 levels to offer further basis to the training interventions used at these levels to improve talent development. Additionally, it would be of interest to assess the physical, technical, and tactical performance differences between the SL and NRL levels. This would enable detailed insights into the performance gaps that may exist between these sub-elite and elite levels that again, could be used as an evidenced-based guide to talent development. This future research would extend upon this foundational work contributing to an even more detailed examination of talent development in Qld RL.

Secondly, the findings of this thesis would be enriched through an interdisciplinary insight into the psychological skills, such as self-regulation, of players across the RLTP. Mental health is a key resource for athletes influencing their development and sporting performance (Schinke, Stambulova, Si, & Moore, 2018). Therefore, identifying individuals with limited capacity of resilience, motivation and self-regulation could inform psychological interventions that further increase the opportunity for successful participation and progression through the RLTP. Concurrently, this would continue to promote the use of interdisciplinary research designs in sport science, thereby creating richer and more holistic athlete support networks (Buekers et al., 2017).

Third, as this thesis explicitly examined the Qld RLTP, similar research could be applied to the NSW RLTP. Notably, it would be of interest to compare the results from this thesis with those stemming from a line of research examining NSW RLTP. Not only would such research enrich the talent development practices of the NSW RLTP, but when combined with the findings of this thesis, it could pave the way for a national talent pathway in Australian RL. Findings may also enrich international talent development programs such as those in New Zealand and the Pacific Islands. As such, while the results of this thesis address critical knowledge gaps of specific use for the Qld RLTP, its learnings offer an enticing platform for future research programs.

Chapter 7 Practical Applications of this Thesis for the Queensland Rugby League Talent Pathway

In addition to the academic contributions made to the field of sport science (evidenced through two publications, and a conference presentation), this thesis has specific practical applications for the Qld RLTP. Most apparently, the results implicate two main areas for improvement: 1) the current organisational structure of the talent pathway; and 2) the design of learning environments intended to assist with talent development implemented by skilled development coaches. This thesis will, therefore, conclude with a description of these two major practical applications for the Qld RLTP.

7.1 Proposed Organisational Changes to the Queensland RLTP

As introduced in Chapter 1, the current Qld RLTP has been designed to follow a somewhat linear pathway, where a talented U18 player transitions into the U20 level and then onto the SL level (refer to Figure 1 in Chapter 1). This progression is seemingly based upon the presumption that the performance gaps between each level are relatively equal, thereby developing the player in a sequential, or stepwise-like manner (Maiden, 2019). However, this thesis has provided evidence contradictory to this notion by showing that these presumed equal performance gaps between levels do not actually exist. Rather, the U18 and U20 levels demonstrated relative homogeneity in contrast to the performance gap seen between these levels and the SL. In recognition of this, the current structure of the Qld RLTP could be reassessed.

Shown in Figure 19, I offer an example of what a RLTP in Qld may look like following a restructure in accord with the findings of this thesis. Most notably, this revised Qld RLTP would see the U18 and U20 competitions amalgamate into a ‘Juniors Competition’ with the intent of maximising resources to augment the development of talented juniors. Ideally, this amalgamated competition would enable the streamlined and centralised use of financial and time-based resources, both of which would likely augment talent development at this junior level. For example, centralised funding may permit clubs to combine resources from U18 and U20 to one squad (Juniors) appointing the most skilled development coach and support staff to work within this program.

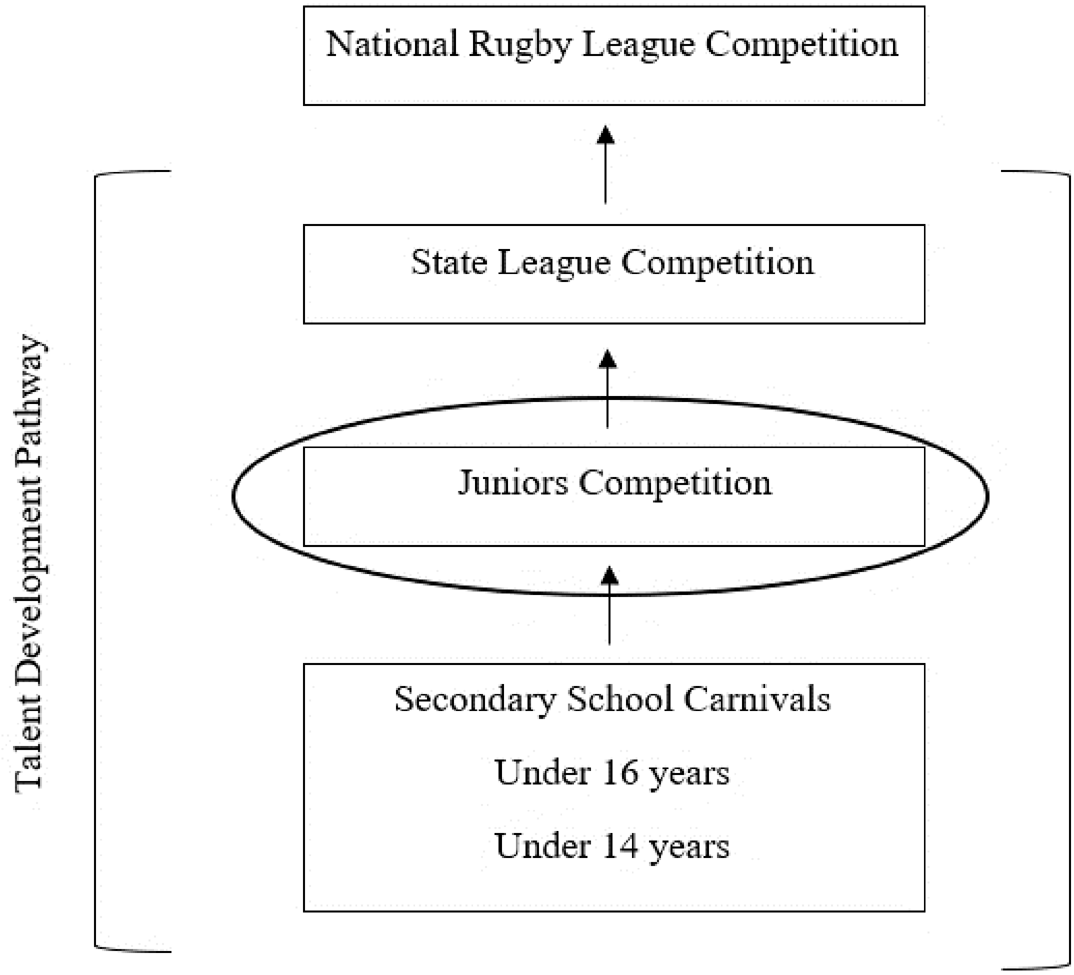

Figure 19. A revised talent pathway in Queensland based on thesis findings.

It is perceived that in this Juniors Competition, all participants would train together in a larger squad. Concurrent with exposure to skilled development coaches, the larger spread in age groupings in this squad conceivably may offer greater diversity in playing experience and capability, thereby exposing players to ‘new’ learning environments as they train and compete against ‘different’ players. Moreover, it is envisaged that the ‘Juniors Competition’ would consist of Junior A and Junior B teams with the ages of participants ranging from 17 to 20 years. This dualistic structure is important as an integral aspect of talent development is inclusiveness (Bailey & Morley, 2006). Although I am proposing the blending of the U18 and U20 levels into one competition, Juniors would still be offered the same participation opportunities as the prior structure. However, these opportunities would now be enriched given the centralisation of time, and resources (e.g. specialised coaches and training regimes) to purposefully enhance athlete development within the Qld RLTP.

7.2 Proposed Learning Environment Design

7.2.1 Physical Training Designs

In addition to the organisational restructure discussed above, the findings from this thesis could assist with the design of practice tasks intended to minimise the noted performance gaps between the junior and SL levels. Firstly, the physical benchmarks highlighted by the ROC curve analysis in Chapter 3 may be used by practitioners to base training interventions intended to minimise the physical gaps between the SL and their junior counterparts. Specifically, qualified strength and conditioning coaches specialising in youth development could implement programs to develop foundational athletic movements, like the SLRDL and DL movements, prior to initiating a progressive-load resistance program. Achieving such foundational movement adaptions, through the use of a tailored resistance training program, including unilateral and bilateral squats and DL lifts is a critical phase of any periodised strength program as it underpins the development of power (Taber, Bellon, Abbott, & Bingham, 2016), a gap also noted between the junior and SL levels in Chapter 3.

7.2.2 Technical Skill Training Designs

As shown in Chapter 4, there were large gaps between the junior developmental level and the SL with regards to passing skill. Accordingly, practitioners at the junior level could use these results to provide opportunities for players to improve passing accuracy at varying distances for both left-to-right and right-to-left passing. To design such practice tasks, coaches could consider the use of small-sided games that promote passing of varying distances, anchoring scoring systems to the execution of passes that reach their intended target on both left and right sides (Gabbett et al., 2009a). Further, as used in Chapter 3, adopting analyses such as ROC curves for passing ability may assist practitioners with the identification of global 'benchmarks' for passing skill assessments described in this thesis.

Chapter 4 also identified gaps between the junior and SL levels with regards to tackling skill with the junior levels showing a predominance of specific tackle type in contrast to the SL participants. Consequently, practitioners could use the tackle criteria listed in Chapter 4 to identify and score technique of the junior players to ensure a dominant tackle is achieved. Again, the use of representative training activities, like small-sided games, that have a specific intent on encouraging a variety of tackle techniques, may offer an appropriate training environment for the development of such tackling skills within the junior levels.

7.2.3 Tactical Training Designs

Chapter 5 highlighted significant differences in tactical skill between 'junior' and the SL participants during an attack play task. To remedy these differences, it is recommended that junior players be more consistently exposed to training activities that challenge problem-solving and opponent evasion (Gabbett et al., 2007). It would be important for qualified development coaches to design training activities that are representative of a game to enable players to formulate ways to evade opponents in contextualised environments. Further, providing the players with instruction that only reflects the desired outcome, coupled with scoring systems that promote successful evasions (e.g. *the ball is to progress to the try line and you will be awarded two points or arbitrary units, if you can successfully evade your opponent in any way possible*), could afford players with the freedom to explore different types of evasive manoeuvres as they attempt to suffice the task goal (Davids, Araújo, Vilar, Renshaw, & Pinder, 2013). Increased exposure to this training design could subsequently accelerate the junior players' capacity to identify opportunities, and then implement actions to evade their opponents (Gabbett et al., 2009a; Magill, 2001).

7.3 Conclusion

The overarching aim of this thesis was to identify the performance gaps between key developmental stages of the RLTP in Qld. Accordingly, physical, technical, and tactical performance qualities were compared between the U18, U20, and SL levels in a series of research studies. As discussed in this Chapter, the knowledge stemming from this thesis could subsequently underwrite relevant organisational changes and training practices used by coaching staff within the Qld RLTP. Ultimately, it is hoped that this will contribute to the goal of producing elite RL performers that will have long and productive careers.

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APPENDIX A

Human Ethics Approval for Studies 1, 2, and 3 (Chapters 3, 4 & 5, respectively).

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