DOCTOR OF PHILOSOPHY

A Comprehensive Investigation to Inform Effective Talent Development in Sport

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Award date:
2023

Awarding institution:
Bangor University

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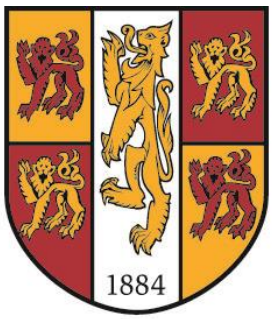

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Declaration

I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards. I confirm that I am submitting this work with the agreement of my Supervisors Dr Gavin Lawrence and Dr Victoria Gottwald. This PhD was funded by Bangor University and UK Sport.

Contents

Acknowledgments

"How's the PhD going Em?"

"…. It's almost Dunn!"

Now that I have delved into the world of primary school teaching, I would very much like to express my thanks to all the teachers that have helped me along my journey. From my teachers at Upottery Primary School to my secondary school teachers at Honiton Community College. I would particularly like to express my thanks to Dr Bawn who was not only an inspiration but a consistent positive role model. A big thanks also goes to Keith Henman and Des Kumar along with Maria, my school and university basketball friends for the countless enjoyable basketball hours I have spent so far during my life.

A big thanks also goes to my colleagues and friends at Combe House Hotel, particularly Ken and Ruth who were always encouraging me to 'FLY!'

Thank you to all the PhD crew in SSHES. Particularly thanks to Ben, Dior, and Seamus for all the talent development conversations over the years.

Regarding the last 5 years, I would like to express my thanks to the following people:

P2P Team. Lizzie, Ben, Tim, Sam, Ross, James, Emma, and Megan. Thank you for all those P2P meetings and EIS opportunities to feedback on the project. These experiences were truly invaluable!

GB EDP Hockey. A big thanks to Heather, Murray, and the Team for their continued engagement and enthusiasm for the project. Thank you to all players that participated within the project, without you I would not have been able to write this thesis. A special thanks to those that additionally took part in the case studies.

Foo. Thank you for convincing UK Sport that they needed to part fund another PhD! Without which, I would not be on the same journey as I am today!

Vicky. Sometimes words are just not enough. This is an instance…I cannot begin to describe how incredibly grateful I am for the impact you've had on me during my university journey.

Elle. It has been brilliant to have worked alongside you during this project. I will never forget the (very last minute) surprise meeting in Lilleshall and data collection trips. 'Good Old Micra!'

Marichi and Georgina. Thank you for all the good times we've had throughout university.

Athy. Thank you always for your positivity and being a critical friend!

Karin and Berwyn. Danke sehr für alles!

Granny & Grandad. Nanna and my family. Thank you for your continued support and love throughout my life. I am incredibly grateful.

Mum and Dad. I just want to say thank you very much for your love and always trying your best. I'm looking forward to seeing you at Christmas!

Tom. Thank you for always being my brother and oldest friend.

Robin Owen. Du bist ein großer Schatz! Vielen Dank für alles, immer.

Late Kate Maura Weeks. A Welsh legend and a true friend. **Diolch yn fawr.**

Pathway 2 Podium Project (P2P project) and my contribution

The P2P project was designed to build on the Great British Medallist project, a multidimensional study which retrospectively investigated the psychosocial and practice and training histories of super-elite and elite athletes (Hardy et al., 2017; Güllich et al., 2017). Funded by UK Sport, Economic and Social Research Council, and Bangor University, the P2P project aimed to overcome limitations associated with a retrospective design (e.g., recall bias), by prospectively tracking the developmental journeys of UK Sport Pathway funded athletes within an elite talent pathway. Following the design of the measures and methodology which had been based on the GBM and developed by the P2P team (7 academic supervisors, 2 senior English Institute of Sport Pathway scientists & 3 PhD candidates), 5 Olympic sports were recruited to the P2P project (Canoe Sprint, Canoe Slalom, Swimming, Rugby, & Hockey).

I led, designed, collected, analysed, interpreted, and wrote all aspects within the present thesis. Specifically, in Chapter 1, I designed the research question, the methodology, undertook the synthesis of both quantitative and qualitative studies, and wrote the systematic review. In Chapter 2, I designed the research question, modified the questionnaires and time points to suit the sport of hockey, collected the data, analysed, interpretated, and wrote the chapter. In Chapter 3, I led on the analysis, interpretation, and write up of the findings.

Following the design of the measures and methods, I worked closely with a senior English Institution of Sport scientist (EIS Pathway) to recruit GB Hockey to the P2P project. This involved several monthly meetings with the Head of Talent of GB EDP Hockey at Bisham Abbey (Berkshire, UK) between March 2019 to September 2019. I attended, contributed, and/or led within these meetings. Following these meetings, a coach engagement day was organised and took place in June 2019 at Lee Valley Velodrome, London. During this day, I presented the project to a group of club coaches and recorded their feedback. Following the feedback, the senior EIS scientist and I introduced the project to the EDP players at two national hockey camps in Lilleshall, Shropshire in September 2019. Data collection then commenced from September 2019 until June 2021. From March 2020 data collection of in-person interviews and surveys were collected over the telephone, due to the arrival of the COVID-19 global pandemic. Following data collection, I presented a total of three formal feedback sessions to GB EDP Hockey and the club coaches of the EDP players who had volunteered to participate in the study. These feedback sessions were either virtual or in person.

Work in addition to the thesis

September 2019 – July 2021

I co-ordinated GB EDP health data via the Performance Data Management System. This involved generating weekly reports that were sent to GB EDP Hockey players and appropriate GB Hockey staff. This helped GB EDP with monitoring both male and female squads for health-related issues throughout the project.

March 2021

I delivered a 10-minute pre-recorded presentation of the preliminary findings from Chapter 2 to all club coaches of the GB EDP players participating within the study.

February 2020

I delivered a 10-minute presentation at an English Institute of Sport (EIS) Pathways Teams meeting. The presentation reported on the progress and experiences of conducting research within elite sport. Additionally, I presented the preliminary pattern recognition findings from the P2P project to the GB EDP staff. Present: Head of Talent, Head EDP Coaches, Head of GB Support, EDP S&C coach, EIS Pathways Senior Scientist and SSHES Senior Lecturer.

I presented a 60-minute presentation of the preliminary findings from Chapter 2 to the EDP hockey staff at Bisham Abby, Berkshire, UK. Present: Head of Talent, Head GB EDP Coaches, Head of GB Support, EDP S&C coach, Head of England Hockey, EIS Pathways Senior Scientist and SSHES Senior Lecturer.

January 2020

I presented preliminary findings from the retrospective practice history interview to the EDP hockey staff at Bisham Abby, Berkshire, UK. Present: Head of Talent, Head EDP Coaches, Head of GB Support, EDP S&C coach, EIS Pathways Senior Scientist and SSHES Senior Lecturer.

March 2019 – July 2019

I contributed within monthly project meetings with GB EDP Head of Talent development (Hockey) and her team in Bisham Abby, Berkshire, UK.

Conferences

May 2021

Dunn, E. (2021). Elite longitudinal talent development research in sport: A systematic review. Poster session presented at The Expertise and Skill Acquisition Network (ESAN) Online 2021.

December 2019

Dunn, E. (2019). International level hockey players' perceptions of high-pressure technical challenge in competitive environments: Preliminary findings. Poster session presented at English Institute Annual Conference 2019, Nottingham, United Kingdom.

October 2019

Dunn, E., Anderson, D., Langham-Walsh, E., Lowery, M., Hardy, L., Lawrence, G., Woodman, T., Gottwald, V., Hardy, J., Roberts, R., & Oliver, S. (2019). *Preliminary Validation of the Athlete Development Formulation Survey (ADFS)*. Journal of Exercise, Movement, and Sport (SCAPPS refereed abstracts repository), 51(1), 115.

June 2018

Dunn, E., Langham-Walsh, E., Lowery, M., Hardy, L., Lawrence, G., Gottwald, V., Hardy, J., Oliver, S., & Roberts, R. (2018). A Prospective Study of The Developmental Biographies of Great British Pathway Athletes: Pathway to Podium.

Thesis Abstract

Despite heavy investment, many talent development pathways are inefficient and at risk of talent wastage (Baker et al., 2017; MacNamara & Collins, 2011). The present thesis aimed to identify multidimensional characteristics that could inform more effective talent development in sport. The aim of Chapter 1 was to systematically review longitudinal quantitative and qualitative talent development and talent selection research to provide an understanding of current characteristics known to be important within effective talent development. Chapters 2 and 3 aimed to address the research lacunas revealed by Chapter 1 through investigation of male and female players' developmental experiences prior to, and progression through, GB Hockey's elite development programme (EDP). Overall, the present thesis advanced the field of talent development and should help practitioners better support athletes through the creation of more effective talent development environments.

Specifically, Chapter 1 advanced the talent development in sport literature as it was the first to systematically review quantitative and qualitative longitudinal talent development and selection research. The review revealed that performance variables (e.g., sprint ability) in quantitative talent selection studies changed non-linearly alongside talent development factors (e.g., maturation). Concurrently, the aggregation of qualitative studies in this review suggested balancing the demands of training and education was challenging, and psychological characteristics in developing excellence (PCDEs) helped athletes overcome these challenges. Importantly, Chapter 1 identified that literature on talent development in sport is currently limited by an overrepresentation of studies comprising quantitative research methods and male-only samples, supporting a need for a holistic investigation into the characteristics that are important for the development of expertise in female athletes.

Chapter 2 built on from Chapter 1 as it addressed the need for more female qualitative research to better understand male and female differences in development of expertise. A case study was chosen to allow comparison of similarities and differences amongst male and female players. The findings suggested several commonalities among sexes that underpinned development of expertise prior to the EDP such as having: a strong work ethic; a pure enjoyment for hockey; experienced a major setback; and a close supportive network. However, differences between male and female players occurred in the type of social support received during development. For example, male players reported having received and benefitted from informational support while female players reported having received and benefited tangible support during development. The findings further highlighted the importance of psychosocial

factors and support the need to investigate multidimensional factors that predict the progression of athletes within an elite talent pathway (e.g., psychosocial development & practice environment). Investigation of the multidimensional factors that underpin progression of athletes within an elite talent pathway will lead to a better understanding of the characteristics needed to be developed in male and female players throughout an elite hockey pathway.

Accordingly, Chapter 3 was the first to identify a pattern of multidimensional characteristics that underpinned progression of male and female hockey players. More specifically, a mixed retrospective prospective design captured practice history (i.e., player demographics, early sporting experiences, volume of practice, milestones & the microstructure of practice) and psychosocial characteristics (e.g., player life experiences, personality & behaviour) within an elite hockey pathway. Pattern recognition-derived models suggested the characteristics that underpinned the male players' progression from the EDP to the GB Senior Squad occurred post-specialisation (i.e., during two time points captured in adulthood). Prior to selection, progressed male players reported completing more blocked practice, less serial practice, and coped better with setbacks. In contrast, characteristics that underpinned the progression of female players occurred both prior to specialisation and post specialisation. Prior to specialisation, female players reported less exposure to anxiety during practice and engaged less in mental skills. They were more likely to have a parent who was a hockey player and had attended a private college at 16 years. Post-specialisation progressed female players perceived less comprehensibility in life but perceived their training environment as less psychologically challenging. Likewise, they perceived to have experienced more serial-varied practice and engagement in mental skills, were at greater risk of mental illness, and were more likely employed during the season.

Overall, this diverse body of work supported and advanced the talent development literature as Chapter 1 further supported the need to investigate talent development holistically, particularly in female athletes using qualitative research methods. Chapter 2 advanced the literature as it identified male and female athletes may require different types of social support during development. Lastly, Chapter 3 further advanced the literature as it identified a multidimensional pattern that underpinned the progression of male and female hockey players in an elite hockey pathway. In conclusion, this thesis supports the need to investigate talent development holistically in both male and female athletes using a diversity of research methods, to better understand how elite sport pathways can develop talent more effectively.

Each chapter followed the American Psychological Association (APA) Style guidelines (7th Ed.). All references from each chapter are presented in the reference list at the end of the

thesis. The numbering system of all figures and tables are reset within each chapter. All co-authors are mentioned within the ‘work in addition to the thesis’ section.

General Introduction

Conceptualisation of Talent

Whilst there is an understanding that talent is needed to achieve success in many domains, whether that is sport (Coutinho et al., 2016), business (Tiwari et al., 2022), or music (McPherson et al., 2021), the concept of talent is difficult to define (Baker et al., 2019). One reason for this difficulty could be due to taking sides in a long-standing nature-nurture debate (Ward et al., 2016). For example, some researchers believe the concept of talent is innate and inherited genetically from parents (Gagné, 2004; Jacob et al., 2018), while some believe talent can be developed through nurture by accumulating hours of deliberate and effortful practice (Ericsson et al., 1993; Davids et al., 2017). Whilst some researchers reside in these polar camps, perhaps a more modern viewpoint embraces both nature and nurture (Ward et al., 2016). Indeed, recent definitions of talent embrace nature and nurture by proposing characteristics of talent can be innate, multidimensional, emergenic, dynamic, and symbiotic (Baker et al., 2019). In which case, characteristics of talent that are needed for sporting success could be both identified and developed over time. Consequently, sport pathways may embrace a concept of athlete potential for success (e.g., Miller et al., 2015). However, a better understanding of talent is needed to support practitioners in their role of identifying and developing athletes within talent pathways (Till & Baker, 2020; Baker et al., 2018). This could be evidenced by the biases that are currently associated within many talent identification programmes. For example, it has been suggested that approximately 2% of athletes that are identified progress to attain international senior success (Güllich et al., 2017).

Talent Identification

Having an inefficient talent pathway is expensive for National Governing bodies (NGBs) who invest millions into talent identification programmes to select athletes who are most likely going to succeed on an international stage (Vaeyens et al., 2009; England & Girginov 2013; Till et al., 2019). One method to identify athletes is through cross sectional measurement of physiological performances, an overrepresented area of talent identification research (Johnston et al., 2017). Consequently, the current talent identification literature is inadvertently contrived with selection biases, whereby talent programmes may select athletes who are relatively older and/or early maturing (e.g. Deprez et al., 2013; Guimarães et al., 2020;

Kelly, et al., 2020; Soares et al., 2020). This is known as the relative age effect (RAE, Cobley et al., 2009) wherein talent pathways are overrepresented with athletes born in the first two quartiles of the competition year (e.g., Tribolet et al., 2018). An overreliance of identifying athletes through physiological characteristics may explain why few athletes enter and stay within a pathway (Güllich et al., 2017). To reduce the likelihood of pathway inefficiency, a better understanding of dynamic and multidimensional characteristics is needed when developing talent (Baker et al., 2020).

Talent Development

Psychosocial, technical, environmental, and physical factors are important to nurture within athletes within a talent development environment, suggesting talent development needs to be investigated holistically (e.g., Rees et al., 2016). Holistic investigation of talent development factors may lead to the creation of a high quality talent development environment (Martindale et al., 2013). An element of a high-quality practice environment is whereby athletes can cope psychosocially with the high demands placed upon them. One mechanism in which athletes may cope is through supportive parents and/or coaches (Baker & Horton, 2004). Coaches are vital in an effective development environment (Sherwin et al., 2017) and therefore having a facilitative coach-athlete relationship is an important element in talent development (Trzaskoma-bicsérdy et al., 2007). For example, coaches' behaviour can provide an autonomy supportive environment, which in turn can meet athletes' basic needs for autonomy, competency and relatedness (Mageau & Vallerand, 2003) and help nurture psychological characteristics such as mental toughness (Li et al., 2019). Having an appropriately supportive environment is key within an effective talent development environment to reduce the risk of dropout (e.g., Thomas et al., 2021). Coaches likewise play an important role in the structure of the practice environment (e.g., Strachan et al., 2011), for example through the knowledge and implementation of practice schedules that vary the contextual interference (e.g., Grecic & Ryan, 2018).

Deliberate Practice

Following the identification and selection of athletes into a talent programme, such programmes attempt to create an environment that most effectively accelerates athletes' skills needed to later perform on an international stage at adulthood (Taylor & Collins, 2020). From a nurture perspective, deliberate practice is an approach to accelerate skill development

(Ericsson, et al., 1993). Deliberate practice is comprised of two components. First, there is an assumption that there is a monotonic benefit between time accumulated in deliberate practice and attainment in expertise (Ford & Coughlan, 2019). Second, deliberate practice is considered cognitively effortful, focused towards improving performance, and not inherently enjoyable. Whilst there is debate surrounding the necessary volume and the type and quality of practice (Henriksen & Roessler, 2011; Forsman et al., 2016), as well as practice hours accumulated in athletes' main and other sports (e.g., Güllich, 2019), deliberate practice has been recognised as an important factor within talent development. Likely because typically successful elite athletes have accumulated a greater volume of deliberate practice by adulthood (Güllich & Emrich, 2014).

Talent Development Models

Long Term Athlete Development Model

In recognition of deliberate practice's contribution to skill development, the long term athlete development model (LTAD) attempts to build onto the principles of deliberate practice by linearly recommending training and competition volume distributions at different ages for different genders (Balyi et al., 2014). LTAD is a talent development model that is frequently adopted in an elite sport talent pathway and is comprised of four stages in early specialisation sports (e.g., gymnastics) and six stages for athletes in later specialisation sports (e.g., hockey). For example, boys aged between 9–12 and females aged between 8–11 years are recommended to experience a 70:30 training to competition split. The volume of training to competition reverses by 18 years in males and 17 years in females such that 25:75 training to competition is recommended. A strength of the LTAD model is it attempts to take sex differences into account within the context of biological maturation. Biological maturation is an important consideration within talent development when considering the performance advantages associated with early maturation, in male and female athletes (Leonardi et al., 2018; Torres-Unda et al., 2013). However, the LTAD model can be criticised by having a monodisciplinary (Ford et al., 2011) focus.

Development Model of Sport Participation

The development model of sport participation (DMSP) is another widely used talent development model that linearly focuses on accelerating skill development at proposed specific

age ranges. Specifically, the model suggests athletes training in later specialising sports (i.e., peak performance occurs in adulthood) should sample a diversity of sports and specialise later. Benefits of early diversification and later specialisation include: enhanced intrinsic motivation; transferable skills; and reduced likelihood of burnout (Côte, et al., 2009). Support for the DMSP can be evidenced in a recent meta-analysis that found world class adult athletes had accumulated more practice hours in other sports, started their main sport later, and had accumulated less main sport practice hours alongside having initially progressed more slowly (Güllich et al., 2021). However, other research suggests relatively more successful athletes can specialise relatively earlier in their main sport, providing their practice was comprised of different types (Sieghartsleitner, et al., 2017). This may suggest whilst these proposed ages can be used as a linear guide, it does not necessarily capture the non-linear training needs of all athletes.

Athletic Skills Model

A more recent talent development model builds upon previous work by incorporating major principles such as early diversification and late specialisation into the model, in a strive towards effective talent development. For example, the athletic skills model (ASM) suggests the importance of 10 physical literacy skills that can be developed through interaction with affordances. The development of fundamental movement skills can occur through play and interaction with their environment, skills such as balancing and catching to name a few. These skills can then transfer into various sports when children eventually specialise (Woemhoudt et al., 2017). The concept of multiple transferable skills was adopted from the DMSP principle of early diversification. Unlike the DMSP, arguably a strength of the ASM is that it does not stipulate an age range in which effective fundamental movement skills should be learnt. In doing so, it further highlights a non-linear element of talent development. Moreover, the model advocates an interaction between generality of practice (e.g., physical literacy skills & non-organised play) and specificity of practice designs. However, due to limited research available, the exact balance and point in development in which athletes train most optimally with specificity and generality of practice is not yet known (Ribeiro et al., 2021).

Holistic Ecological Model

In line with the ASM, which acknowledges the role of non-linear talent development and multidimensional affordances within the environment, Henrikson et al (2010) proposed

two models as part of a holistic ecological approach (HEA) to talent development: the athlete talent development environment model (ATDE) and the environment success factors model (ESF model). The ATDE model is comprised of a macro and micro levels in relation to the environment. Macro-level factors important to talent development could be national culture and the educational system. Micro-level factors important to talent development could be athletes' family and athlete peers. The ESF model suggests the importance of interacting factors such as the type of practice and training and organisational culture. The HEA approach highlights the important role of the environment beyond the individual athlete by specifically focusing on the environmental factors that can interact with the athlete. A strength of the HEA is it takes a multidimensional perspective by incorporating psychosocial characteristics as important factors within talent development.

Psychosocial Characteristics

Psychosocial characteristics are important to consider within talent development pathways because they can be considered relatively more and less stable with time depending on athletes' stage in life (Bleidorn & Hopwood, 2019). Psychosocial characteristics likely interact with the environment (e.g., Roberts & Woodman, 2017) and contribute to athletes thriving within a talent pathway (Brown et al., 2017). Taken together, these research studies could suggest psychosocial characteristics can develop differently at different stages during talent development (Subotnik, Olszewski-kubilius, & Worrell, 2011). Within elite sport, little is known about how psychological characteristics change over time and what is known is ambiguous (Rongen, 2020). Considering psychosocial characteristics (e.g., self-determined motivation) can interact with the quality of practice (Hendry, Crocker, & Hodges, 2014), longitudinal examination of how psychosocial factors develop in male and female athletes is needed (Gledhill, et al., 2017).

A further need for longitudinal psychosocial research can be highlighted by Hardy et al., (2017). This was a retrospective qualitative study that examined a mixed sample of male and female athletes across different sports. By adulthood, super-elite athletes (i.e., serial medallists at international competitions) had developed a different profile of psychological characteristics, training behaviour and life experiences in comparison to elite athletes (i.e., athletes who finish within the top ten of international competitions). Specifically, super-elite athletes had developed stronger characteristics of obsessives/perfectionism, selfish and/or ruthlessness towards their training and/or competition. Additionally, super-elites had

developed a relatively higher importance of sport, adopted counterphobic and/or total preparation approach towards competition and combined an outcome and mastery focus; all factors that aided robust performance under pressure. However, it is unclear how and when these psychosocial characteristics developed and to what extend these characteristics were developed (i.e., by nurture) or were innate. Indeed, a mixed sample of athletes and sports mean it is unclear whether super elite male athletes developed a different psychosocial profile to female athletes and whether different psychosocial profiles are better suited to different sports. Therefore, an investigation is needed to better understand male and female psychosocial differences during development prior to an elite talent pathway.

Psychological Skills

In addition to a better understanding of the development of psychosocial characteristics, psychological skills may be useful to investigate longitudinally as studies have shown psychological characteristics can benefit elite athletes in both team (e.g. Heydari & Soltani, 2018) and individual sports (e.g., Blijlevens et al., 2018). The use of psychological skills vary by sport (e.g., golf v weightlifting) and different aspects of psychological skills may benefit male and female athletes differently. For example, Einersson et al. (2020) revealed that male athletes used self-talk more frequently in competition and practice in comparison to female athletes. Female athletes used more emotional and attentional control strategies during practice and more relaxation, automaticity, emotional control during competition. Taken together it suggests the benefit and type of psychological skill may depend on sport, environment (i.e., competition v practice), sex (male and female), and age. Subsequent, longitudinal investigations that analyse males and female athletes separately will help better understand use and effectiveness of psychological skills throughout development.

Mental Toughness

Another key psychosocial skill to develop during the talent pathway is mental toughness. Although the definition of mental toughness is not widely agreed, athletes who show mental toughness typically display behaviours such as being able to maintain concentration and confidence under pressure and be able to achieve their goals consistently (Kristjánsdóttir et al., 2018; Thom, et al., 2020). Additionally, mental toughness can associate with strong personality factors such as extraversion, emotionality, and conscientiousness

(Yankov et al., 2019). Developing mental toughness in athletes is desirable within talent pathways because typically, the higher the mental toughness, the higher the performance level (Cowden & Cowden, 2017). A key consideration for practitioners to consider however, in the appropriate development of psychological skills, is the stage in athletes' cognitive and maturational development. Between ages 10–15 years, self-talk and relaxation may not be as appropriate to develop in comparison to goal setting and mental imagery (Mccarthy et al., 2010). Due to a lack of longitudinal and potential biases in research reporting, understanding when (i.e., age) and how psychosocial characteristics develop within athletes is not well understood (Gledhill et al., 2017). Understanding interactions between practice and competitive training environments and psychosocial development may be an important consideration for coaches when structuring an appropriately challenging and effective talent development environment. For example, exposure to a competitive environment can impact athletes' psychological development (Smith et al., 2020). However, this study only examined male athletes. Therefore, whether exposure to a competitive environment is better suited to male athletes is not yet well understood (Gledhill & Harwood, 2019; Gledhill et al., 2017).

Microstructure of Practice

Context and Anxiety Specific Practice

Effective learning is proposed to occur when a movement of a target skill is closely matched along with the environmental conditions in which that target skill will be used (Henry, 1968). This is known as the specificity of practice hypothesis. In more recent years, the specificity of practice hypothesis has been extended to include anxiety. Specifically, performance under anxiety conditions was better when the motor skill was learnt under pressurised conditions (Lawrence, et al., 2013). However, it should be noted that the extension of the specificity of practice hypothesis was suggested by a study that utilised a cross sectional design, in a mixed sample of male and female athletes. Therefore, it is unclear whether both male and female athletes would benefit from learning a skill under pressurised conditions. Indeed, little is known at which age in development pressured training is most appropriate, due to the variability in psychosocial development. Therefore, investigation is needed to better understand when in development (age) context and anxiety specific practice is most beneficial to accelerate skill development and whether there are male and female developmental differences.

Practice Schedule

Contextual interference occurs when an athlete engages in practice that features greater degrees of between-skill randomness (i.e., practicing more than one skill in a random order) and within-skill variability (i.e., practicing skills with varying situational parameters such as shot distance, Yanci et al., 2013). Whilst contextual interference has shown to promote long term retention of an acquired skill, much of the literature has been conducted within a laboratory setting (e.g., Porter & Magill, 2010). Consequently, these findings are more difficult to generalise to a talent pathway because of the low ecological validity. However, coaches can manipulate contextual interference and the challenge of practice by adjusting practice schedules (Farrow & Buzzard, 2017). For example, coaches may plan more varied random practice instead of blocked constant practice. According to the challenge point framework, a challenging environment can be created by manipulating the task difficulty and amount of feedback (i.e., knowledge of results) relative to the skill level of athletes (Guadagnoll & Lee, 2004). Whilst research has shown super-elite athletes have accumulated a greater volume of contextual interference during development (Jones et al., 2020), the use of a retrospective design and a male-only sample mean it is not yet clear in this study how much contextual interference is needed and the age it is most beneficial to accelerate skill development, especially in female athletes.

Thesis Rationale

In sum, creating an effective talent development environment is complex. Likely because talent is multifaceted, dynamic, and frequently examined in silos (Rees et al., 2016). Often research examines physiological performance, in male-only samples, using cross sectional and retrospective designs. Consequently, talent identification programmes are currently inefficient (Güllich et al., 2017). To strive towards improving the efficiency of talent pathways, a greater understanding of effective talent development is needed. Future directions for talent development research advocated the use of multidimensional and longitudinal designs in male, and particularly female athletes from a diversity of sports, using multiple research methods (Baker et al., 2020; Johnston et al., 2018). However, this literature has not yet investigated talent development from a development and talent selection perspective. Therefore, we currently do not know whether longitudinal literature has taken a holistic approach by investigating factors that impact both development and talent selection. A combined talent development and selection lens may not have yet been taken because of the

complexity involved. However, with the emergence of non-linear pattern recognition models, talent development research has begun to analyse complex multidimensional and dynamic interactions (e.g., Owen et al., 2022; Langham-Walsh, 2021; Barth et al., 2020; Jones et al., 2020; Anderson 2020). Indeed, whilst these studies have investigated multidimensional talent development characteristics that underpinned effective talent development in team (Owen et al., 2022), mixed (i.e., inclusion of athletes from different Olympic sports, Bath et al., 2020), and individual sports (e.g., Anderson, 2020; Langham-Walsh, 2021), these studies examined either a male-only samples or mixed samples of male and female athletes. To our knowledge no study has yet to investigate multidimensional characteristics that underpin effective talent development in male and female hockey players. Therefore, using pattern-recognition models and a mixed methodology, the aim of the thesis is to advance the talent development literature by identifying multidimensional characteristics that inform effective talent development in hockey.

Chapter 1: Thirty Years of Longitudinal Talent Development Research: A Systematic Review and Meta-aggregation

Abstract

Talent pathways are longitudinal and multidimensional in nature. They offer long-term developmental environments for athletes that incorporate multiple processes at multiple timepoints (e.g., to detect, identify, develop, and select talent). Recent reviews have unilaterally targeted static talent areas (i.e., talent detection and identification). The present systematic review aimed to provide holistic understanding of talent by considering longitudinal development *and* selection literature collectively, to greatly advance our understanding of effective talent development in sport. The present review followed Preferred Reporting Items for Systematic Review and a Meta-aggregation methodology. A search of talent development and selection literature identified 41 quantitative and 3 qualitative studies. Bias was assessed in each study with talent development studies having the greatest variability in bias. Overall findings suggested multidimensional selection characteristics (i.e., measures of performance) changed non-linearly with talent development characteristics (e.g., practice environment and psychosocial maturation). For practitioners, these findings may suggest the practice environment and psychosocial development may interact with athlete performance during talent development. Additionally, with the present review highlighting a lack of female qualitative research, future studies could be designed to investigate psychosocial developmental differences between male and female athletes. In doing so, these findings can inform effective talent development by better supporting individual differences and reduce the likelihood of talent wastage during talent development.

Introduction

Recent literature suggests the concept of talent can be multifaceted, multidimensional, and dynamic (Baker et al., 2019). A delay of a concrete definition of talent suggests talent programs do not currently have optimal guidance for effective talent development (Baker, et al., 2017). To better operationalise and define talent, literature suggests four areas pertinent to talent pathway systems. Talent detection finds potential athletes suitable for consideration of talent programs. Talent identification formally invites athletes into talent programs. Talent development aims to provide an environment to accelerate athletes' potential. Talent selection measures athletes' performance during talent development (Reilly et al., 2000; Till & Baker, 2020).

A consideration of talent programs and talent research within distinct areas (e.g., detection, identification, development & selection), allows for a clearer understanding of what is known and what limitations are currently present within existing literature (Williams et al., 2020). So far, talent identification, detection and selection studies could be considered as any study that examines a (multidimensional) performance characteristic (e.g., Huijgen et al., 2014). Within the literature many studies have examined performance characteristics in silo (e.g., Johnston et al., 2018), likely due to practicality constraints associated with complex and time-consuming designs, when working in an elite sport environment (Farrow et al., 2018). This may explain why an examination of talent detection and identification has been popular and widely reviewed (Baker et al., 2020; Faber et al., 2017; Gledhill et al., 2017; Johnston et al., 2018; Koopmann et al., 2020). We so far understand there is an overrepresentation of studies that have primarily examined physiological characteristics (Johnston et al., 2018; Koopmann et al., 2020; Murr et al., 2018) and employed cross-sectional designs mainly in male samples. Adopting a cross-sectional design is likely popular because it also lends itself to the somewhat static nature of these talent processes (i.e., a snapshot measurement).

In contrast, talent development studies could be considered as any study that examines a (multidimensional) characteristic that helps or hinders performance (Gagné, 2004) and/or development, whilst a talent selection study could be considered as any study that examines a (multidimensional) performance characteristic (e.g., Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2014). Arguably, the difference between a talent detection / identification study and a talent selection study is the latter has a dynamic element (i.e., a multidimensional performance characteristic is measured across multiple time points during development, to monitor performance), whereas the former has a static element in nature (i.e., a snapshot measure of performance prior to talent development, specifically with the purpose to detect or identify talent). Currently, talent development and selection research has received less attention, likely due to the dynamic and complex nature outlined. Despite this dynamic and multifaceted definition, many studies have employed cross-sectional designs and examined talent development characteristics in silo, resulting in a dearth of longitudinal and multidimensional talent development research (Rees et al., 2016; Burgess & Naughton, 2010).

There is currently a lack of understanding how both talent development and talent selection studies longitudinal interact (Williams et al., 2020). The presented novel approach in design is a step towards greatly advancing our understanding because it highlights factors that

may impact talent selection, during the process of talent development. Taking a holistic approach to better understand the dynamic factors that impact selection during development, is currently not understood and is therefore needed to advance and unite the respective literatures (Baker et al, 2022; Dehghansai et al., 2022; Wrang et al., 2022). This combined approach is important when considering athletes' level of performance during a talent pathway determines whether they are selected to continue to be developed or deselected out of the talent program (Baker et al., 2018). With a dearth of longitudinal designs, it is currently more challenging for researchers to inform talent programs in providing optimal long-term support because athletes do not follow linear trajectories and expertise is developed over many years (Gulbin et al., 2013; Ericsson et al., 1993). Investigating longitudinal multidisciplinary talent development research that include environmental characteristics (e.g., coaching & practice structure), and their respective impact on talent selection during talent pathways, will greatly advance long-term athlete support during development; especially when considering individual differences (Phillips et al., 2010).

The aim of this systematic review is to provide holistic understanding of talent by considering longitudinal talent development *and* selection literature collectively, to greatly advance our understanding of effective talent development and selection in sport. To our knowledge, no review has attempted to systematically review both quantitative and qualitative longitudinal research across more than one talent area (i.e., talent development & selection). In doing so, we hope to encourage and direct future longitudinal and multidisciplinary research by providing fruitful avenues of research to help better inform talent pathways in providing more effective long term athlete support during development, whilst reducing the likelihood of talent loss/wastage, currently observed within talent programs (Baker, et al., 2018; Johnston & Baker, 2020).

Methods

Design

Due to the broad research question of a complex and dynamic topic (talent development and selection), we present a mixed knowledge review design that incorporates a research synthesis (PRISMA) and other knowledge synthesis (meta-aggregation), to create a meaningful, and epistemologically congruent, evaluation of longitudinal talent development and selection research in sport (Gough et al., 2012). We followed the PRISMA checklist and

guidance from the PRISMA group (Moher et al., 2015; Page et al., 2021a; Page et al, 2020b). In line with the PRISMA guidance, we created a PRISMA protocol (Page et al., 2021a; Moher et al., 2015). To synthesise qualitative studies, we followed a meta-aggregation method in line with guidance from Johana Briggs Institute (Hannes et al., 2010; Lockwood et al., 2015; Munn et al., 2015; Shamseer et al., 2015). A meta-aggregation method ensured we did not re-interpretate the authors' original findings, enabling findings to be recommended to inform practice (Lockwood et al., 2015).

Eligibility Criteria

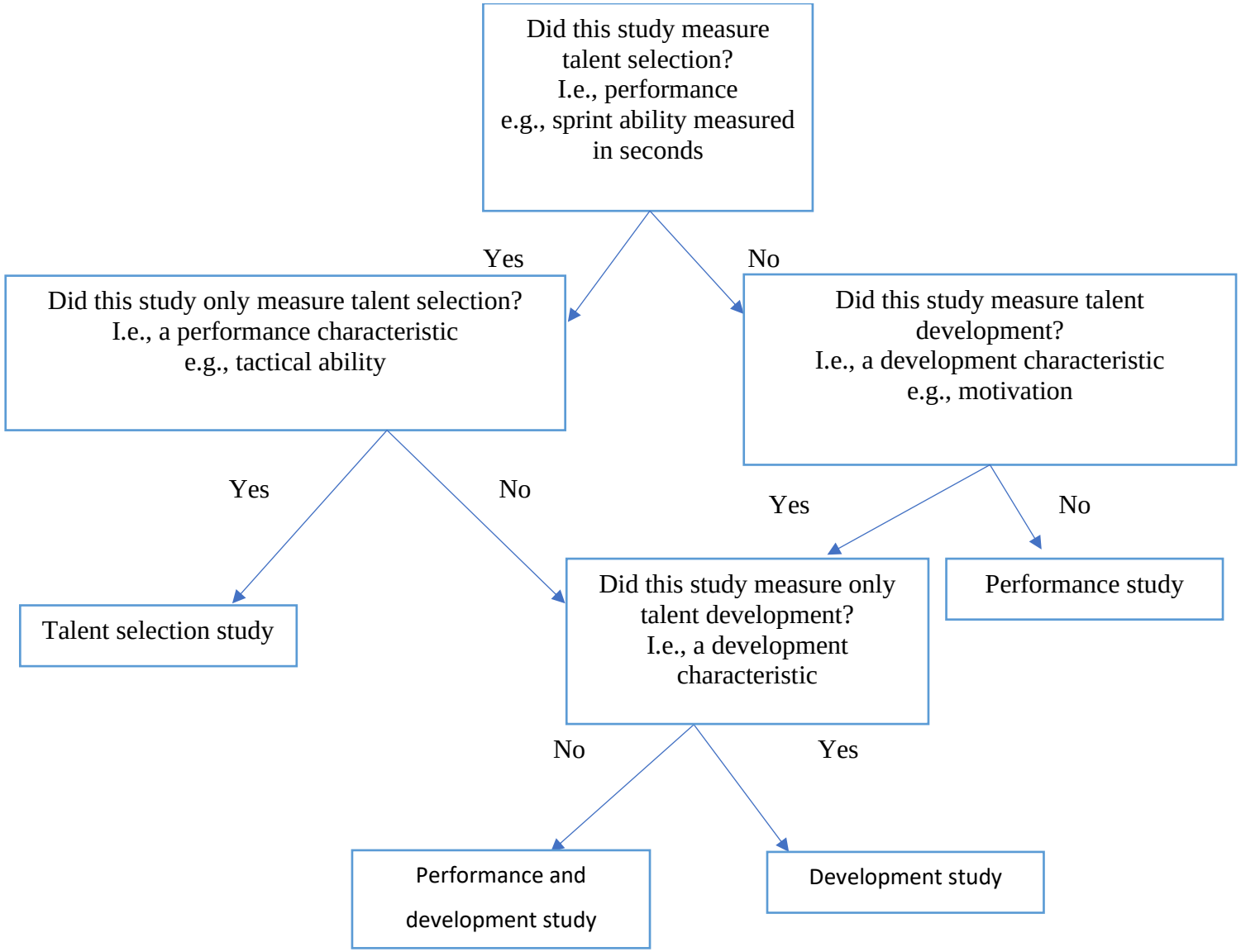
Studies were included if they had; 1) a longitudinal panel design; 2) a minimum of two time points measured for a minimum duration of 12 months; 3) at least one group of athletes that trained or represented a minimum of a national level (Johnston et al., 2018; Baker, 2015; Rees et al., 2016); and 4) been through the peer review process and were written in English; 5) been published between January 1990 and January 2020. Studies were excluded if they had talent "identification" within their title or abstract. Moreover, studies were excluded if they had assessed the predictive validity of performance characteristics between higher or lower skill groups (e.g., Schorer et al, 2020). Assessing studies for at least a minimum two time points measured within a minimum 12-month duration attempted to capture a dynamic aspect within talent development (i.e., talent development and selection literature).

To secure a better understanding of potential characteristics impacting talent development and selection, it was important to define talent development and talent selection studies within the literature. We considered and included a talent development study that measured a change in a multidimensional (i.e., physiological, psychosocial & technical) characteristic that helps or hinders performance and/or development. For example, symptoms of burnout could be considered to negatively impact characteristics pertinent within talent development, such as performance goals and motivation (e.g., Daumiller et al., 2020; Bicalho et al., 2018). Therefore, a longitudinal study of burnout (that met the inclusion criteria) would have been categorised as a talent development study and included within the review (e.g., Isoard-Gautheu et al., 2015). In contrast, we categorised a talent selection study if it had measured a performance characteristic at multiple time points (e.g., tactical skill) during development (e.g., Kannekens et al, 2009a). We therefore categorised and excluded talent identification or detection studies which measured a single time point of performance. For example, a study may have assessed the predictive validity of a performance characteristic by

observing adulthood selection into differentiating performance groups (e.g., Schorer et al., 2020; Höner et al., 2021). Based upon the above definitions, we categorised a talent development and selection study as those studies which measured both a development and performance characteristic, at multiple time points within the same study. One example is Elferink-Gemser et al (2006). They assessed changes in motivation and endurance performance. See Figure 1.

Figure 1

A Logic Diagram Depicturing the Process of Categorising Included Studies



Search Strategy

Search 1 and 2. We used two electronic search platforms, Clarivate Web of Science, and Science Direct to search relevant databases in life science research (e.g., Medline & BIOSIS Citation Index™). Limits to the search ensured that studies were journal articles published between January 1990 – January 2019, peer-reviewed, and published in English. We undertook the search of key terms in January 2019. Specifically, the following search terms were entered manually into each database "Expertise AND Sport", "Talent AND Development AND Sport", "Longitudinal Design AND Academy Athletes", "Longitudinal Talent Development AND Sport", "Longitudinal Athlete Design", "Longitudinal Athlete Development".

Study Selection

Studies were screened by their title and abstracts. We read the full text if a study could not be determined from reading the title or abstract. The authors agreed on the decision to include studies. All included studies underwent full screening using a reference management tool (Mendeley Desktop, Elsevier, Netherlands). To find additional studies, we scanned the reference lists of included studies and applied the same inclusion and exclusion criteria. Automated tools were not used and therefore we used Microsoft excel (Microsoft, USA) spreadsheet for data extraction. We extracted authors, title, year of publication, study design, duration of study (months), sport, level of athlete (national or above), number of time points examined, main findings, statistical analysis, and conclusion.

Quality Assessment

We used two JBI critical appraisal checklists to assess quantitative and qualitative studies for bias and methodological rigor (Moola et al., 2020). Two researchers independently assigned "include", "exclude" or "seek further info" to each study. For any discrepancies or studies that were assigned "seek further info", we consulted another member within the research team. Both checklists assessed methodological quality through the possibility of bias during the study's design, conduct and analysis. The checklists comprised 11 and 10 items, respectively. Additionally, we established the dependability and credibility of synthesised qualitative findings with CONqual (Lockwood et al., 2015).

We calculated a percentage quality score which assessed methodological rigor for each study and assigned an overall mean score to the talent selection, talent development and talent selection and development categories. According to Faber et al. (2016) and Sarmento et al. (2018b), a ≤50% study has low methodological rigor, a 51% to 75% study has good methodological rigor, and a ≥75% study has excellent methodological rigor. The methodological rigor within talent selection studies ranged between good and excellent (56–88%); the methodological rigor ranged between low and high (44–100%) in talent development studies; and between low and high (56–86%) in talent selection and development studies.

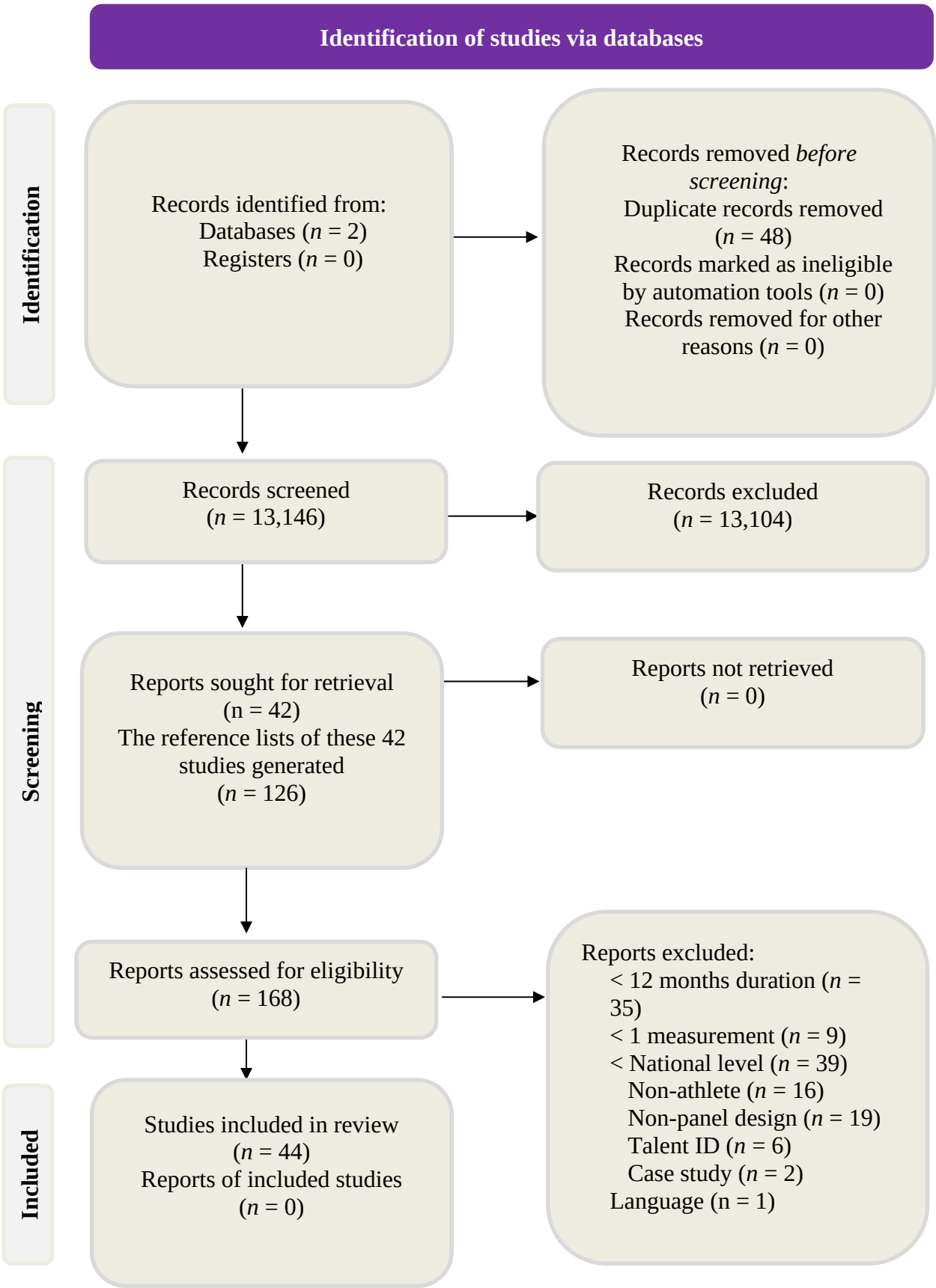
Results

Data Extraction and Synthesis

Search 1 (January 2019) and Updated Search 2 (August 2020). We searched the Web of Science and Science Direct search platform which collectively identified 13,194 citations in search 1. Following the removal of 48 duplicates, two researchers scanned the title and abstract of 13,146 records. Of the scanned records, 13,104 studies did not meet the inclusion criteria. Of the 42 included records, 126 additional records were identified from scanning the included records' reference list. Therefore 168 full-text articles were assessed for eligibility. Of the eligible studies, 125 records were excluded (see Appendix 1). In total, 43 studies (40 quantitative & 3 qualitative) were included. Search 2 (January 2019 – August 2020) identified 5,228 citations. Of which no duplicated were recorded. One researcher scanned the title and abstract of 5,228 records. Of the scanned records, 1 study met the inclusion criteria and aggregated within the review. Therefore, in total 44 studies (41 quantitative & 3 qualitative) were included. We deemed a narrative synthesis as most appropriate because of the variation in research methods (Roberts, et.al., 2006).

Figure 2

A PRISMA Flow Diagram (Page et al., 2020)



Descriptive Statistics

In total, 44 studies used either quantitative (*n*=41) or qualitative research methods (*n*=3). Across these research methods, studies measured either talent development characteristics (62%), talent selection characteristics (14%) or talent development and talent selection characteristics simultaneously (24%). Studies that measured talent development characteristics primarily examined a mixed sample of male and female athletes (61%), whilst studies that examined talent selection characteristics primarily examined a male only sample (83%). Those studies that examined talent development and talent selection characteristics primarily examined a male only sample (80%). Across all categories, longitudinal studies were typically published between 2016–2020.

Talent Selection Studies

In total, the methodological quality of 6 longitudinal talent selection studies were rated between good and excellent 56–88% (See Table 1). Studies found performance improved non-linearly with age (Clark et al., 2008; Kannekens et al., 2009; Keiner et al., 2014; Leyhr et al., 2018; Stoter et al., 2020; Wiersma et al., 2017). Specifically, jump performance increased in male soccer players between 9–12 years (Keiner et al., 2014), technical performance improved between U12-U15 (Leyhr et al., 2018), and tactical performance improved between 14–18 years (Kannekens et al., 2009). In male and female speed skaters, tactical performance improved later, between U17–U19 (Wiersma et al., 2017), and technical performance increased between 17–18 years (Stoter et al., 2020). In adulthood, anaerobic threshold increased between 25–28 years, whilst aerobic power remained stable in male soccer players (Clark et al., 2008).

Table 1.

Included quantitative longitudinal talent selection studies.

Reference	Subcategory	Duration (months)	Characteristics	*N*	Sport	Sex	Quality score (%)
Clark et al., (2008)	Physical	36	Aerobic power and anaerobic threshold	42	Soccer	M	56
Kannekens et al., (2009)	Mental	84	Tactical performance	191	Soccer	M	88
Keiner et al., (2014)	Physical	24	Jump performance	70	Soccer	M	75
Leyhr et al., (2018)	Multi-dimensional	36	Motor and physical performance	1134	Soccer	M	63
Stoter et al., (2020)	Technical	48	Knee and push off angles during competition	123	Speed skating	M/F	70
Wiersma et al., (2017)	Mental	36	Tactical performance	104	Speed skating	M	75

Talent Development Studies

In total, we rated talent development studies' methodological quality between low (44%) and excellent (100%). Of 28 (n = 25 quantitative or n = 3 qualitative) longitudinal studies, 19 studies found anthropometric characteristics changed with age (e.g., Bilsborough et al., 2017). Specifically, between 16–18 years, cartilage thickness increased (Culvenor et al., 2017; Eckstein et al., 2014; Wirth et al., 2014) and ligament / tendons strengthened (Mersmann et al., 2017). Changes in abnormal patellar tendons were found alongside years of training and bone mineral density (Schöffl et al., 2007) which predicted injury in basketball (Giombini et al., 2013), soccer (Fredberg & Bolvig, 2002) and rugby (Georgeson et al., 2012). However, abnormal patellar tendons or training between 13–15 hours/week did not always predict overuse injury (Gisslén et al., 2007; Schöffl et al., 2018). Although male and female differences were found in the development of injuries (Cook et al., 2000; Habechian et al., 2018; Helenius et al., 2002). Whilst late maturing male and female athletes were at risk of overuse and frequent injuries (Kolt & Kirkby, 1999; Maïmoun et al., 2013; Van Der Sluis et al., 2015), late maturing athletes were not always at greater risk of injury across all sports (Rudavsky et al., 2018a), and abnormal tendons could reverse post peak growth (Rudavsky et al., 2018b).

When considering psychological characteristics, there were male and female differences found in the development of burnout signs with female athletes being at a potentially greater risk of developing signs of burnout (i.e., sport devaluation) between ages 14–19 years and emotional / physical exhaustion appeared to be attenuated by sport devaluation (Isoard-Gautheu et al., 2015). Despite male and female differences in signs of burnout, intrinsic motivation predicted deliberate practice in both male and female basketball and volleyball players (Vink et al., 2015). The longitudinal qualitative studies revealed a transitional period challenged athletes to balance life, education, and training in national development programmes. Both male and female athletes perceived balancing high education and transitioning into a talent program as challenging. Lifestyle support alongside, psychological characteristics in developing excellence (PCDE skills), and planning for retirement, may help overcome challenges (Devaney et al., 2018; MacNamara & Collins, 2010; Torregrosa et al., 2015).

In male athlete development, general cognition increased between 10–15 years and sport-specific cognition increased later between and 12–15 years (Beavan et al., 2020). Psychosocial characteristics changed between 13–17 years; level of stress, hope for success,

self-optimisation, and self-concept decreased (Feichtinger & Höner, 2015), whilst recovery increased, and need satisfaction, quality of school life, and athletic identity remained stable (Rongen et al., 2020), along with self-determined motivation which decreased between U15–U17 (Hendry et al., 2019).

Table 2.

Included quantitative longitudinal talent development studies.

Reference	Subcategory	Duration (months)	Characteristics	*N*	Sport	Sex	Quality score (%)
Beavan et al. (2020)	Mental	36	Cognitive development	304	Soccer	M	75
Bilsborough et al. (2017)	Physical	26	Body composition	45	Australian football	M	83
Cook et al. (2000)	Physical	16	Injury risk in patellar tendons	52	Basketball	M/F	86
Culvenor et al. (2017)	Physical	24	Cartilage development	40	Volleyball	M/F	71
Eckstein et al. (2014)	Physical	24	Cartilage development	40	Volleyball	M/F	71
Feichtinger and Höner (2015)	Mental	24	Training behaviours	151	Soccer	M	75
Fredberg and Bolvig (2002)	Physical	12	Injury	54	Soccer	M	50
Georgeson et al. (2020)	Physical	12	Body composition and injury	37	Rugby	M	50

Giombini et al. (2013)	Physical	36	Injury	37	Fencing	M/F	57
Gisslen et al. (2007)	Physical	36	Injury	22	Volleyball	M/F	63
Habechian et al. (2018)	Physical	36	Injury	31	Swimming	M/F	71
Helenius et al. (2002)	Physical	60	Airway inflammation	42	Swimming	M/F	56
Hendry et al. (2019)	Mental	24	Self-determined motivation	63	Soccer	M	100
Isoard-Gautheu et al. (2015)	Mental	36	Burnout	895	Handball	M/F	78
Kolt and Kirby (1999)	Physical	18	Injury	62	Gymnastics	F	100
Maimoun et al. (2013)	Physical	12	Bone density and biological maturation	72	Gymnastics and Swimming	F	90
Mersmann et al. (2017)	Physical	24	Tendon development	82	Skiing	M/F	90
Rongen et al. (2020)	Mental	12	Psychological characteristics	115	Soccer	M	86
Rudavsky et al. (2018a)	Physical	24	Maturation and tendons	52	Ballet	M/F	44

Rudavsky et al. (2018b)	Physical	24	Maturation and tendons	52	Ballet	M/F	56
Schöff et al. (2007)	Physical	60	Skill level, training, and osteoarthritic changes	40	Climbing	M/F	75
Schöff et al. (2018)	Physical	132	Range of motion and osteoarthritis changes	37	Climbing	M/F	78
Van der Sluis and Elferink-Gemser (2015)	Physical	48	Maturation and injury	120	Soccer	M	33
Vink et al. (2015)	Multi-dimensional	12	Deliberate practice and intrinsic motivation	163	Volleyball & Basketball	M/F	80

Table 3.

A meta-aggregation of included qualitative studies. All findings were rated as unequivocal using CONqual.

Finding	Category	Synthesised finding
Athletes faced challenges when transitioning into an NDP. Some athletes found it difficult to control emotions.	Transitioning is a process for higher skilled athletes who are challenged to balance education with training in NDPs.	Higher skilled athletes are challenged to balance education with training in NDPs. Lifestyle support, PCDE skills, and planning for retirement, may help to overcome challenges.
Athletes can find it difficult to adapt and manage competing demands between education and NDPs.		
Players acknowledged the value of gaining clarity over what they want to become, when faced with tension created between uncertainty and identity negotiation.		
Athletes perceived transition to university as a process.		
Athletes used psychological characteristics in developing excellence (PCDEs) to overcome challenges.	Lifestyle support alongside, PCDE skills, and planning for retirement may help to overcome challenges.	
Players appreciated lifestyle support.		
Athletes who could balance job/education with a NDP had a stronger sense of identity, perceived social support, had an active coping strategy and was able to plan for retirement.		

Included studies: MacNamara et al (2010); Torregrosa et al (2015); and Devaney et al (2018)

Talent Development and Selection

In total, the methodological quality of 10 studies were rated between good and excellent (56–86%). Studies found physical, technical, and psychological performance improved non-linearly with age. For example, whilst physical, technical, and psychological performance improved with age (Elferink-Gemser et al., 2007; Güllich, et al., 2017; Hendry, et al., 2018; Huijgen, et al., 2010; Roescher et al., 2010), anthropometrics (Matthys et al., 2013), and training (Elferink-Gemser et al., 2006; Visscher & Lemmink, 2006), physical, technical and psychological performance remained stable in male soccer players between 12–14 years (Forsman et al., 2016) and reflection skills remained stable between 17–20 years in male basketball players (te Wierike et al., 2018).

Table 4.

Included quantitative longitudinal talent selection and development studies.

Reference	Subcategory	Duration (months)	Characteristics	*N*	Sport	Sex	Quality score (%)
Elferink-Gemser et al (2006)	Multidimensional	36	Anthropometrics, motivation, and endurance capacity	217	Hockey	M/F	67
Elferink-Gemser et al (2007)	Multidimensional	24	Anthropometrics, psychological characteristics, physical, technical, and tactical performance	65	Hockey	M/F	86
Forsman et al (2016)	Multidimensional	12	Psychological characteristics and physical, technical, and tactical performance	288	Soccer	M	57
Güllich et al (2017)	Multidimensional	24	Organised practice, non-organised play and coach rated player performance	44	Soccer	M	71
Hendry et al (2018)	Multidimensional	36	Coach rated performance and athlete perception of tactical, technical, physical skill	102	Soccer	M	86

Mattys et al (2013)	Multidimensional (Physical)	60	Anthropometrics, maturation, and physical performance	207	Soccer	M	75
Huijgen, et al (2010)	Multidimensional	36	Physical, technical, performance and years of soccer practice	53	Handball	M	63
Roescher et al (2010)	Multidimensional	60	Intermittent endurance capacity, practice history and anthropometrics	130	Soccer	M	56
te Wierike et al (2018)	Multidimensional	48	Ball control and self-regulation	73	Basketball	M	67
Visscher & Limmink (2006)	Multidimensional	36	Intermittent endurance capacity and training volume	137	Soccer	M	67

Discussion

The present review highlighted that the past 30 years of talent research has primarily examined studies solely within silos (i.e., talent development or selection). Those studies that measured talent development and selection characteristics simultaneously suggested physical, psychological, and technical performance can increase non-linearly with age when measured alongside anthropometric, practice and training, and psychosocial characteristics. Examination of longitudinal talent development characteristics highlighted later maturing male athletes may be at risk of overuse injury around peak growth, female athletes may be at risk of burnout, and both male and female athletes may experience challenges when transitioning into a talent pathway. Examination of talent selection characteristics suggested performance characteristics increased with age. In line with previous talent reviews, different athlete populations were underrepresented particularly female athletes, athletes who identify as LGBTQ+, athletes with a disability, and/or athletes' race or ethnicity (Baker et al., 2020; Johnston et al., 2018; Koopmann et al., 2020). Studies have typically adopted quantitative research methods. Future research needs to longitudinally investigate talent development and talent selection characteristics simultaneously (e.g., multidimensional performance, maturation, and injury incidence).

Maturation, Development, and Selection

Biological maturation can impact both talent development and selection (Towlson et al., 2021a) because there is evidence to support a relative age effect, whereby early biologically maturing athletes can have a physiological advantage over late maturing athletes (e.g., Cumming et al., 2018; Smith et al, 2018). Recent evidence and commentary suggest the stage in biological maturation may account more when explaining observed superior displays of physical performance in adolescence (Towlson et al., 2021b). Perhaps then biological maturation may partially explain why this review found sprint performance increased most rapidly between 14–16 years. It therefore may be pertinent for practitioners to take biological maturation into account during talent selection in adolescent development (Towlson et al., 2021b), especially considering differences in physical performance may dissipate between approximately between ages 16–18 years (DiFiori et al., 2018).

Around peak growth, biological maturation may also increase the risk of overuse injury in some athletes. In the present review, talent development studies highlighted that later

maturing male athletes may be at risk of over-use injury around peak growth (Van Der Sluis et al., 2015). Therefore, for late maturing athletes who are currently completing the same training load as their age-matched early maturing athletes, may be undertaking more load at their joint and tendons than needed. Consequently, inadvertently increasing male athletes' likelihood of injury and possible deselection. Injury risk factors in talent programs are currently not well understood, possibly due to differences in the type of injury, such as traumatic or overuse injury (Kolokythas et al., 2021; Müller et al., 2017; Rejeb et al., 2019; Steidl-Müller et al., 2020; Swain et al., 2018; Wik et al., 2020), and differences in athlete population (e.g., females; Alahmad, Kearney, & Cahalan, 2020). Understanding sex differences and the potential role of biological maturation and psychosocial maturation is important given that over-use injuries can terminate athlete careers (Mueller et al., 2017). Talent programs need to take into consideration athletes' sex, stage of biological and psychosocial maturation when managing training load.

Less research has examined psychosocial maturation, particularly in sport. Psychosocial maturation is a largely unexplored talent development factor that may begin to unpick individual differences. For example, whilst logic reasoning can be developed by age 15 years, psychosocial maturity can continue to develop into adulthood (Steinberg, 2004; Steinberg, 2007) and may impact psychosocial characteristics important within elite sport, such as decision making (e.g., Miller et al., 2011). Therefore, psychosocial maturation may be pertinent talent development characteristic for practitioners to consider as it may impact talent selection. When considering psychosocial maturation can occur after biological maturation (Gluckman & Hanson, 2006), perhaps then later psychosocially maturing athletes could explain why tactical and technical performance improved later in adolescence in some sports (e.g., U17–U19, Wiersma et al., 2017). However, this was not the case for all sports (e.g., 14–18 years, Kannekens et al., 2009). Indeed, individuals may take until their late 20s to be fully psychosocially mature (Icenogle et al., 2019). Later psychosocially maturing athletes may even require a different practice environment to accelerate technical performance, given the role of self-regulation and psychosocial characteristics in skill development (Young & Starkes, 2006; Carvalho & Araújo, 2022).

When considering athletes can be either early, on-time, or late to biologically mature, it is likely that psychosocial maturation follows a similar pattern. Indeed, a combination of biological and psychosocial maturation may perhaps explain why physical, psychological and technical performance improved non-linearly with age (García-De-Alcaraz Serrano et al., 2015; Sarmento et al., 2018a; Stoter et al., 2020; Vaeyens et al., 2006; Wiersma et al., 2017). Specifically, perhaps athletes do not mature both physically and psychosocially at a linear rate

(Malina et al., 2015). Therefore, athletes may find themselves being early to biologically mature, but late to mature psychosocially or vice versa. Perhaps a mismatch between biological and psychosocial maturation may explain why some late biologically maturing athletes have developed superior psychosocial characteristics (Baker et al., 2010; Schorer et al., 2009; Jooste et al., 2019; McCarthy et al., 2016) and survive talent pathways (Gibbs et al., 2012), whilst others appear to be doubly disadvantaged (Rubajczyk et al., 2017). Identifying psychosocially late athletes may be a strategy to potentially reduce a current relative age bias within a talent pathway and help target interventions (Dixon et al., 2020), which may reduce the likelihood of talent wastage of doubly disadvantaged athletes.

Future Directions

The present discussion highlights biological maturation, and particularly psychosocial maturation, may impact both talent selection and development and increase the likelihood of injury. Longitudinal research is needed to investigate interactions between maturation, injury, and performance as talent programs may currently be inadvertently nurturing early maturing athletes and disadvantaging later maturing athletes which may be likely contributing to talent wastage (Guimarães et al., 2019; Guimarães et al., 2019; Torres-Unda et al., 2013). One strategy for talent programs and research to reduce the likelihood of talent wastage is the use of physiological and psychosocial bio-banding. Bio-banding is whereby athletes are matched both by the stage in biological and psychosocial maturity, rather than chronological age (Cumming et al., 2017).

Prospective investigation of factors that enable progression in psychosocially delayed athletes is currently unexplored and could be important given the rise in research linking effective practice environments with psychosocial characteristics (Guadagnoll & Lee, 2004; Güllich, 2014; Young et al., 2021). Perhaps then the microstructure of practice could be adjusted to better suit the stage of psychosocial development as an attempt to accelerate skill development and performance. A consideration of psychosocial maturity in talent development may impact the current talent pathways' structure. For example, it may perhaps be more beneficial for later psychosocially mature athletes to follow a zigzag pathway. A zigzag pathway is structured to allow athletes to move in and out of a talent program (Gulbin et al., 2013; Lascu et al., 2021). A zigzag approach and philosophy may be particularly beneficial in later adolescence (i.e., >17 years) when technical and tactical ability can further improve. Other benefits to a zigzag pathway include potentially reducing the pressure to specialise early and

potentially reducing the risk of anxiety, humiliation, and loss of athletic identity associated with deselection. Ultimately a zigzag approach may perhaps reduce the likelihood of talent wastage. Although a shift in philosophy may welcome immediate criticism (e.g., funding and resource constraints), it is an ideology that with time and collaboration could perhaps be made efficient.

Limitations

Firstly, due to practicality in conducting a broad, meaningful review, the exclusion of talent identification studies was necessary to allow for a practical and meaningful synthesis of talent development and selection research that may impact talent development. Secondly, the search of only academic journals may have limited the generation of studies. To mitigate a risk of studies being missed we took an approach in line with a previous systematic review that searched the reference list of included studies (Johnston et al., 2018). The search of reference lists yielded 126 additional studies. Secondly, exclusion of mixed-longitudinal designs and retrospective longitudinal designs is worth noting considering these designs are often more practical within the talent development literature (Till et al., 2017; Valente-Dos-Santos et al., 2012). Thirdly, because our aim attempted to capture long-term talent development, consequently acute longitudinal changes in characteristics in a sporting season (i.e., <12 months) may have been missed (e.g., Granados et al., 2008). Finally, including an elite athlete population as an inclusion criterion may have increased the risk of potentially missing studies due to the differing standards in sports between nations (Bennett et al., 2019).

Conclusion

In conclusion, little research in the past 30 years investigated both talent development and selection factors simultaneously. Those studies that did suggested physical, psychological, and technical performance increase non-linearly with age when measured alongside anthropometric, practice and training, and psychosocial characteristics. An interaction between biological maturation and psychosocial maturation may explain why performance increasing non-linearly within development and provide a potential fruitful avenue for future longitudinal talent development research. Additionally, with a lack of qualitative and female research, future research needs to investigate developmental experiences in female athletes. In doing so, these findings can inform effective talent development by better supporting individual differences and reduce the likelihood of talent wastage during talent development.

Chapter 2: An Investigation of Male and Female Hockey Player Experiences Prior to GB Elite Development Programme

Abstract

The talent development literature is currently overrepresented by quantitative studies that have investigated a male-only or mixed sample of athletes. Therefore, there is a lack of rich data that captures the experiences of female athletes that led to the development of expertise. Driven from a pragmatic epistemology and critical relativism ontology, we took a deductive–inductive approach by use of a semi-structured interview to explore the developmental journeys of male and female players. A reflexive thematic analysis highlighted commonalities and differences amongst four hockey players prior to the EDP. Common themes identified having developed a strong work ethic, a pure enjoyment for hockey, experienced overcoming of a major setback, and relied upon a close and supportive network, to help navigate and overcome the challenges during development. Differences between male and female players were found in perceptions of social support received from their caregivers. Male players reported having benefited from hearing a different perspective which helped them overcome challenges and find solutions. In contrast, female players reported having benefitted from being driven to training and competitions. These findings provide further evidence to support the notion that specific psychosocial characteristics and experiences are needed to attain expertise, irrespective of sex. Nuanced sex differences in social support preferences provide an insight into areas in which talent development pathways could offer more individualised support for male and female players. Offering individualised social support may promote long term engagement through the creation of a more effective talent development environment.

Introduction

The talent development literature has been overrepresented by studies which have investigated physiological characteristics and quantitative designs in male-only or mixed samples of athletes (Rees et al., 2016). Consequently, these physiological findings do not generalise well to female athletes because of the physiological differences between male and female athletes (e.g., Henry et al., 2001; Dimundo et al., 2021). Less is known about complex psychosocial differences that occur within the development of male and female athletes because of the quantitative studies that have investigated psychosocial characteristics that are important to talent development. For example, personality traits (e.g., Roberts & Woodman, 2017; Murr et al., 2018); life experiences (Collins & MacNamara, 2017); coach-athlete

relationship (Jowett, 2008; Bjørndal & Ronglan, 2018; Skrubbeltrang et al., 2021); and motivation (Coutinho et al., 2016). Accordingly, one weakness of quantitative psychosocial talent development studies is that they do not capture complex interactions between athlete and their environment as well as qualitative analysis (Gustafsson et al., 2008).

A recent qualitative study however advanced the literature by retrospectively investigating multidimensional psychosocial and practice and training characteristics that discriminated between super-elite and elite athletes (Hardy et al., 2017). This semi-structured interview schedule explored the following six themes: 1) critical developmental experiences (e.g., John et al., 2019; Hardy et al., 2017; Howells, 2020); 2) relationship with sport (e.g., Geary et al., 2022; Von Rosen et al., 2018; Knights et al., 2016); 3) pressure zone and emotional regulation (e.g., Yasar et al., 2020; Saward et al., 2020; Doron & Martinent, 2021); 4) personality (e.g., Murr et al., 2018); 5) relationship with family and coaches (e.g., Galatti et al., 2019; Jowett & Arthur, 2019); and 6) career turning points (e.g., Andersson & Barker-Ruchti, 2019; Ekengren et al., 2019). According to the study's psychosocial findings, the authors highlighted super elite athletes had experienced a negative life event alongside a positive sport-related event, a career turning point that enhanced motivation for their sport, specific personality traits (i.e., obsessiveness, need for success, ruthlessness & perfectionism), and both a mastery and outcome focus as well as a relatively importance of their sport. Whilst the qualitative nature of this design allowed for detailed themes to emerge, a limitation of this study however was the use of mixed sample of athletes. Therefore, it is unclear whether super-elite female athletes had the same developmental experiences as super-elite male athletes.

Examination of female athletes is important given the gender gap that exists within the talent development literature (Curran et al., 2019). Moreover, recent reviews of talent research found in agreement that there is currently an overrepresentation of studies that have used male-only or mixed samples of athletes (e.g., Johnston et al., 2018; Baker et al., 2020). Whilst there can be similarities amongst male and female athletes in the way in which they communicate (Sullivan, 2004), this has not always been the case (Watkins & Lewis, 2016). For example, although the authors caution not to overgeneralise male and female communication styles, they argue that females may prefer a relatable and personal communication style whilst males prefer to be direct and assertive (Merchant 2012; Stewart, 2016). This may suggest that male and female athletes may have different psychosocial needs within a coach-athlete relationship and their sporting journey.

Knowing which psychosocial characteristics are important to develop and when will inform sporting talent pathways because currently early sporting success in childhood is not always a reliable factor to predict success at adulthood (Barreiros et al., 2014; Boccia et al., 2017; Güllich et al., 2021), likely because of the multifaceted and non-linear nature of developing talent (Rothwell et al., 2022). Consequently, current talent development pathways in practice have a low predictive validity and a high number of dropouts across different sports (Grossmann et al., 2015; Steidl-Müller et al., 2019). Therefore, a better understanding of sex specific differences needed to develop talent effectively may help reduce the likelihood of dropout. Especially when considering sporting pathways currently do not necessarily adjust their pathways to best suit the needs of male and female athletes (Mukherjee et al., 2016).

This aim of the current study therefore was to investigate male and female psychosocial differences in hockey players prior to the sporting talent pathway. This is to better understand the complexity of male and female characteristics that are needed to attain expertise (i.e., an elite hockey talent pathway). The present study took a deductive–inductive approach. A deductive approach was taken by investigation of six research derived themes from the findings of Hardy et al (2017). Specifically, critical developmental experiences, relationship with sport, pressure zone and emotional regulation, personality, relationship with family and coaches, and career turning points. These six themes were interweaved organically around their account of their developmental sporting journey to the EDP. An inductive approach was also taken as the players were free to explore these themes in any direction.

Methodology and Methods

Theoretical Standpoint and Sampling

To better understand the developmental sporting journeys of four hockey players, our approach was pragmatic in nature and observed through an experiential lens, which explores the meanings, views, and perceptions of players (Braun & Clarke, 2021b). This lens was underpinned by a critical realism ontology which acknowledges positivist ontology with an interpretivist epistemology (Smith et al., 2012). Essentially, the approach assumes that there is one objective truth (external reality), however we socially construct our own knowledge of that external reality (Heeks et al., 2019; Smith et al., 2012). The paradigm assumes flexibility to

solve real-life practical problems (e.g., Ryba et al., 2022) and suggests knowledge is created through our shared experiences (Morgan, 2014; Kaushik & Walsh, 2019; Patton, 1990; Poucher et al., 2020; Holt et al., 2018). For an overview of paradigms, see Patton (1990) and for an overview of epistemological assumptions and ontological beliefs see Poucher et al (2020) and Sparks and Smith (2014).

To ensure rigorous qualitative research (e.g., Smith & Smith, 2014; Braun & Clarke, 2022), careful consideration of our methodological approach informed our choice of semi-structured interview and type of thematic analysis (i.e., reflexive thematic analysis). Adopting a critical realist ontology provides a flexibility to adopt semi-structured interviews that is underpinned by deductive and inductive reasoning (Vealey, 2008; Sparkes & Smith, 2014). Specifically, we used research derived pre-determined themes and inductive reasoning to explore players' developmental journeys whilst being open and reflective to new themes that were constructed during data analysis (Braun & Clarke, 2019). Therefore, the most appropriate approach for data analysis was one of reflexive thematic analysis (Braun & Clarke, 2019). These methods and analysis were chosen because they can adopt a pragmatic stance that has the flexibility to embrace a critical realism ontology and acknowledge the role of the researcher in the social construction of knowledge.

In line with our methodological approach, we purposefully sampled players through maximum variation sampling (Sparkes & Smith, 2014; Smith et al., 2016), meaning at least one male and female player trained and competed as a goalkeeper, whilst at least one male and female trained and competed within an outfield position. We chose maximum variation sampling of GB EDP male and female hockey players because we wanted to identify common patterns that emerged across variations within GB EDP hockey players (Patton, 1990). Importantly, identifying common experiences that occurred irrespective of sex and position will greatly impact the effectiveness of talent development and selection within pathways because it potentially highlights approaches to the construction of a talent environment that talent pathways can and cannot share across squads.

Data Collection

Interviewer Background. I (Emily Dunn, BSc Hons, MRes, PGCE, PhD candidate) have had three formal years training in qualitative research methods which included attended qualitative and mixed method research workshops (UK), annually delivered undergraduate

qualitative research method lectures, and completed numerous hours of independent study during my postgraduate studies at Bangor University. Throughout the write-up, particularly during the collection and reflexive thematic analysis, it was important to reflect on how my own biases may impact the construction of knowledge. This is particularly pertinent within talent development, having trained within an elite development squad during my own adolescence (England Basketball, 2008–2009), and more recently represented Great Britain amateurs in two UCI Gran Fondo World Cycling Championships (2016–2017 Perth, Australia & Albi, France) at adulthood. In line with Braune and Clarke (2022) to ensure good quality themes and coding, I took a dual process of emerging and distancing. I emerged myself within the data by re-reading the transcripts and listened to the audio recording many times. I distanced myself from the data by analysing the findings over several months (i.e., between December 2021 – July 2022). This importantly allowed time for reflection and several iterations of thematic maps (two of which can be found in appendix one and two) whilst analysing the data. This enabled me to re-emerge myself within the data and help me understand why I was interpretating the data in a particular way.

Procedure

I recruited players face-to-face during a male and female EDP training camp in September 2019, where players consented to participate in the wider P2P study. As part of the initial recruitment, players were given an information sheet that explained all aspects of the project including the case study. Players knew that data collection was a part of a PhD project and were reminded that they were volunteering to take part, their responses would be anonymised, and that their response would not inform any talent selection made by GB EDP. Following discussions with the GB EDP pathway manager, male and female outfield and goalkeeper players were selected. In total, four players agreed to participate within the case study. By the time I interviewed the players, they had been participating within the study for 1 year (9 months) meaning I had naturally built a positive rapport enabling a relaxed atmosphere during the interviews. Building a positive rapport this is important to help players provide an accurate account of their developmental journeys (Lincoln & Guba, 2005). Due to COVID-19 restrictions, the single interview took place over Zoom, or Skype. All participants were happy to keep the cameras on throughout the interview. No one else was present during the interview. An audio device recorded the interview and was professionally transcribed by verbatim.

Interview Schedule

The interview schedule of Hardy et al (2017) was used to explore the developmental journeys of super-elite and elite athletes. Open questions and prompts were used to allow players to talk freely and elaborate (Hodge et al., 2014; Smith, 2010). Whilst participants were aware of the themes of interest, these themes were weaved organically within the interview after asking an opening question: "can you tell me about your hockey journey from as early as you can remember?" As the interviewer, I used prompts to help gain a richer insight to their developmental experiences (Smith et al., 2016). An effort was made to keep the interview to 1 hour in length. However, in line with a reflexive thematic analysis, whereby meaning is generated through the interpretation of *what* was said as opposed to *excavating everything* in a form of data saturation (Braun & Clarke, 2021a), the amount of content, and overall direction of the interview was dictated by each player. See Table 1 for player characteristics.

Table 1.

Case Study Player Characteristics

Players	Sex	Age	Length of interview	Position
Player 1	M	22	39:13	Outfield
Player 2	F	23	36:37	Goalkeeper
Player 3	F	24	50:25	Outfield
Player 4	M	20	50:22	Goalkeeper

Data Analysis and Validity

To investigate developmental differences in the journeys of male and female GB EDP hockey players, we explored the meaning of the data through both semantic coding, meaning we identified explicit meanings from the words used by the players (Byrne, 2022). During this process, I made relevant notes to the literature which helped as part of immersing ourselves within the data. Moreover, I reflected on the data, as well as reflecting on my own assumptions in how I was interpretating the data (Braun & Clarke, 2020).

I followed the six-phase guidance to undertake reflexive thematic analysis using comment function and tables in Microsoft Word: 1) Familiarisation with the data; 2) Generating initial codes; 3) Generating themes; 4) Reviewing potential themes; 5) Defining and naming themes; and 6) writing a report (Braun & Clarke, 2012; 2013; 2014; 2020; Byrne, 2022). During phase 1, we ensured that we were familiar with the data by reading the transcribed verbatim several times, whilst also listening to the recording to gain greater context to what and how was being said. In phase 2, we worked systematically through the transcript to code any items that could be useful when address the research purpose (e.g., code 1: identifying as a close family). During phase 3, we generated themes by constructing meaning across the data codes (Braun & Clarke, 2013; Byrne, 2022). For example, code 1 (identifying as a close family) was aggregated with similar codes (e.g., supportive parents, parents were a hockey role model, parents & siblings' relative perceptions of pressure etc.). These aggregated codes formed a theme (i.e., Importance of parental and family support during development). After creating the initial thematic map (See appendix 1), phase 4 involved reviewing the themes in relation to the coded items this helped inform the final thematic map (Figure 1). Phase 5 involved naming the themes to capture concisely what had been constructed from the dataset. Finally, phase 6 writing up a meaningful report in the convention of reflexive thematic analysis involved synthesising and contextualising data within the findings/results section, which Braun and Clarke (2022) prefer to call 'Analysis' because it avoids the suggestion that knowledge has been found within the data and that this knowledge is definite; hence why there is not a 'Discussion' section per se within this chapter (Braun & Clarke, 2013; 2022; Byrne, 2022).

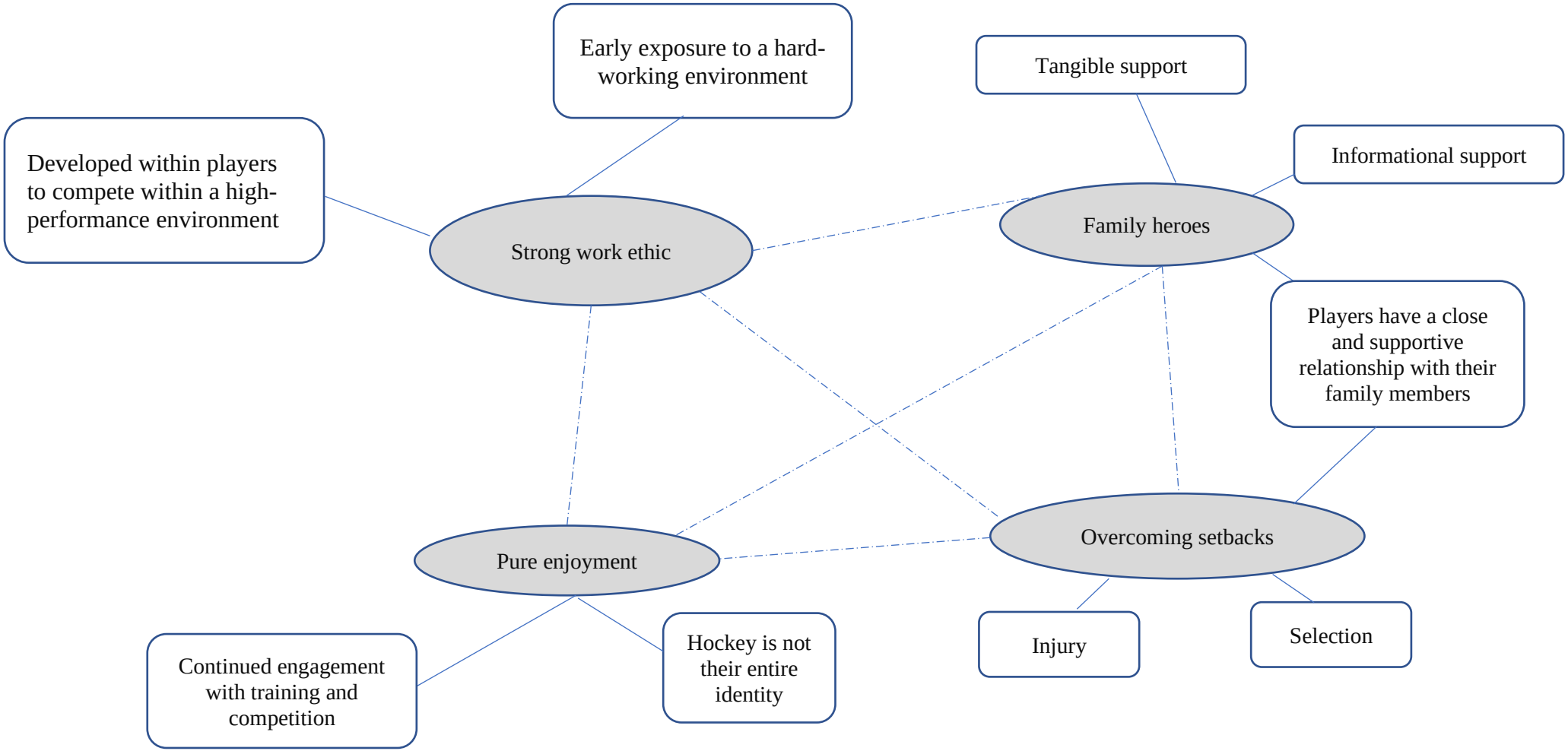


Figure 1. A final Thematic Analysis Map displaying aggregated themes which was reached following a process of reflection and re-reading each transcript several times (Braun & Clark et al., 2006; 2012; 2013; 2016; 2020; 2022). See appendix 1 & 2 for initial generation of themes.

Analysis

Family Heroes

Parents and family members can be an important source of social support within athletes (Baker et al., 2003; Lundy et al., 2019).

"*If ever I've needed advice on anything, you know, they're both always there.*"

~ Player 1

"*…If I'm ever struggling with something or want some advice, it will definitely be a phone call with one of them.*"

~ Player 4

"*They're all very supportive, but my dad is the main person for my hockey.*"

~ Player 2

"*…We had a European and a Junior World Cup, and they would come in face paint, they had drums, they had horns, those vuvuzela things…*"

~ Player 3

Players who have attained an international level of hockey, irrespective of sex, reported having a supportive parent within their developmental hockey journey, as illustrated by the extracts above and "*My parents were great with the sport side of things.*" (Player 1) and "*They could not have been more supportive, when we were growing up.*" (Player 3). However, the type of social support received varied amongst male and female players. For example, female players tended to report perceptions of tangible support "*They were literally the best taxi-drivers, driving us here, there and everywhere.*" (Player 3), and "*…my dad is the one who will drive me to all club games on a weekend…"* (Player 2), whereas male players tended to perceive informational support from parents as it helped provide an alternative outside perspective "*I'd speak to my mum a lot because she's nothing to do with hockey…*" (Player 1); parents "*…don't know anything about hockey, which is brilliant…*" (Player 4) because "*it's nice to get that perspective on things sometimes and just ask her honest opinion on things.*" (Player 1). Having social support is widely regarded as an important element within effective talent development (Sheridan et al., 2014). Differences between perceived type of social support between male and female athletes may be an important element for talent pathways to consider. In line with the present findings, research has suggested that female athletes prefer not to receive

emotional and tangible support from parents (Hassel et al., 2010). Whilst Olympic athletes tended to not know which types of support they needed, they reflected that what they did receive was enough, of which they highlighted examples of tangible support from their support providers (Poucher et al., 2018). In contrast, during adolescence (12–17 years), informational and emotional support seemed to be most important for male and female athletes when faced with competition stressors (Kristiansen & Roberts, 2010; Sutcliffe et al., 2021). This could perhaps explain why male players particularly reflected "*…giving that outsider's perspective has probably helped…especially growing up – 16, 17, 18 that was probably key then."* (Player 4) and "*Even in relation to hockey, it's kind of good, because they never can coach me as such, but it's just generic perspective.*" (Player 4). Taken together these findings may suggest that the type of social support may be more suited to male and female players during adolescence. Ensuring players have access to the social support that they need, may be key within the creation of an effective talent development environment (Kristiansen & Stensrud, 2020; Knight et al., 2018).

Strong Work Ethic

Having a supportive network is important in development especially when combined with a strong work ethic (Henriksen & Stambulova, 2017).

"*…I just try to work as hard as I can and enjoy it at the same time.*"

~ Player 1

"*You would never achieve anything without hard work...*"

~ Player 4

"*I think that's definitely my super strength…I'll put 110% in.*"

~ Player 2

"*I've always wanted to work hard. I've always wanted to do well.*"

~ Player 3

Players reported having a strong work ethic from an early age which perhaps could have been mediated through exposure to a hard-working environment from an early age such as via parent(s) "*You work hard and then you can go and enjoy yourself with sport.*" (Player 4), or "*It's fine for someone to be better than you, but there's no excuse for anyone to work harder than you.*" (Player 2). Or a strong work ethic may have developed within the players when they recognised it can be beneficial within a

competitive environment. "*The main way I operate is just work hard and try to outwork people really.*" (Player 1) In doing so, some players adopt work ethic to become their "*…biggest strength, just putting my head down and working as hard as I can…*" (Player 1). Having "*…had to balance school and sport, or some kind of work…*" the development of a strong work ethic may have positively impacted training behaviour later in development by having "*…had to develop the ability to time-manage well and be organised.*" (Player 3). For example, "*Even if I'm not doing anything until later in the afternoon, I'll get out what I'm going to wear for the gym...*" (Player 3). Developing a strong work ethic in elite sport, particularly in Olympic, Paralympic, World Champions and professionals, is an important characteristic to develop (Burns et al., 2019; Hardy et al., 2017; Gould et al., 2020). For example, having a strong work ethic may help athletes overcome setbacks, which are to be expected within a developmental journey (Jowett & Spray, 2013).

Overcoming Setbacks

Setbacks are common within a developmental journey and therefore athletes need to be able to overcome setbacks (Jowett & Spray, 2013).

"*I missed out, that first year, by quite a way. That was really disappointing…*"

~Player 1

"*…every time you have a setback, you just keep trying harder and harder, because you don't want to not get picked…*"

~Player 4

"*…I think the number of times I've nearly retired, it's unbelievable, but I think…you've always defeated the odds before, so just keep going a little bit more.*"

~ Player 2

"*I'm quite resilient, in that it would almost appear that the setbacks and the deselections haven't really affected me, because I just kind of get on with it…"*

~ Player 3

All players had either experienced a selection setback at some point within their hockey developmental journey. Overcoming these experiences, one player felt an enhanced motivation to succeed "*I'm motivated to never feel like that again…*" (Player 4), whilst others drew upon work ethic to help overcome a selection setback "*I just kind of get on with it, and just carry on working hard…to hopefully put me in the right position*

in the future." (Player 3). Using strong work ethic as a mechanism to overcome challenges can be supported by a recent systematic review, which highlighted when work ethic is developed in young athletes, it can help to overcome challenges during development (Dohme et al., 2019). Players may likewise rely on social support to help them re-appraise the selection setback. "*My parents were really supportive through that. I just carried on, went again the next year and managed to get in.*" (Player 1). Reappraising the situation is particularly illustrated in Player 2 "*There are some girls who aren't in the programme anymore…when you ask why they left, they said, 'Oh, I got dropped', but because I've done it so many times, a bit like, well, what do you mean? Isn't that just part and parcel?*" Taken together, these findings suggest talent pathways could better support players during development and rehabilitation by promoting a strong work ethic and/or reappraising the situation when overcoming a selection or injury setback (Mosewich et al., 2014).

A Pure Enjoyment for Sport

Promoting an enjoyment for sport is important when creating an effective talent development environment (e.g., Wilkinson et al., 2020; Strachan et al., 2011).

"*…the main reason I do it is because I just really enjoy it... I've always enjoyed it.*"

~ Player 1

"*…I love it and I enjoy it and it makes me happy…*"

~ Player 4

"*Like, 60%, I do it for fun and enjoyment…*"

~ Player 2

"*People have been…what are you still doing? I think I just really enjoy playing hockey.*"

~ Player 3

Promoting enjoyment within a talent development environment is important because it may encourage long term engagement (Wendling et al., 2018; Wylleman, 2019; Murray & Sabiston, 2021), reduce a likelihood of dropouts (Gledhill et al., 2017), overcome setbacks (Bennett et al., 2022; Kim & Tamminen, 2022), and help players cope within an elite sport environment. "*I think, when you play at international tournaments and things, you've got to enjoy the pressure, else it's going to be a pretty difficult experience.*" (Player 1). Indeed, enjoyment was important within the continuation of their

hockey development "*I wouldn't do it still if I didn't enjoy it at all...*" (Player 2), "*...because if you're not enjoying it, why are you doing it?*" (Player 4).

Enjoyment can help athletes develop resilience (Sarker & Page, 2020), and resilience may help athletes overcome an injury setback (Gonzalez et al., 2016; Codonhato et al., 2018). Perhaps enjoyment may likewise be important to help players overcome a major injury. For example, Player 2 reported a major injury setback that made her consider retirement during her development. During this injury setback, Player 2 changed her goal from international hockey to non-competitive hockey "*...when I first did it, I thought, I'm just going to get back fit for my own sake, but I'm going to retire from international hockey...because I knew I'd been dropped, it was like...I just want to play hockey for fun now.*" By searching for enjoyment in hockey however, Player 2 gradually re-introduce herself back to elite hockey. Perhaps importantly, "*Like, I didn't come back to play international hockey, that was the difference...I came back just to go and play socially.*"

In the case of Player 2's situation, taking a break helped her fully overcome her major injury setback by helping her to re-evaluate her goals (i.e., playing hockey non-competitively or competitively on an international stage). "*...I mean, that lasted about three weeks before I signed for a prem club.*" (Player 2). At the time of the interview, Player 2 positively spoke about her future hockey goals. "*My intention has always been to do two Olympic cycles, so Paris and LA will be the aims...*" Whilst, Player 2's experience is a single real-life example of non-linear talent development, it may perhaps highlight the importance for talent development environments to have an inbuilt zig-zag system (Gulbin et al., 2013; Lascu et al., 2021) which enables players to step away from sport and re-enter at a later point, especially after setbacks. If talent pathways can adopt a zigzag philosophy to talent development, it may be one important step towards reducing the likelihood of talent wastage in hockey and elite sport.

Applied Implications

The current findings support the talent development literature by highlighting that irrespective of sex, it is important for elite athletes to have a strong work ethic (e.g., Burton et al., 2008; Henriksen & Stambulova, 2010), a pure enjoyment for their sport (e.g., Zanatta et al., 2018), social support (e.g., Sheridan et al., 2014), and have overcome a setback (e.g., Jowett & Spray, 2013). Research suggests social support (i.e.,

informational, emotional & tangible) is important for both male and female athletes in childhood (Holt & Morley, 2004). The qualitative and holistic nature of the present study further advances the talent development literature by highlighting there are multiple psychosocial factors that are likely important to create an effective talent development environment, in addition to adequate social support. Whilst sporting pathways could use these findings (i.e., strong work ethic) as a predictor within a talent identification (Rosevear & Cassidy, 2019; Guenter et al., 2019), these psychosocial factors may be more useful to monitor within players during talent development. For example, sporting pathways could monitor enjoyment levels alongside strong work ethic to assess players' level of engagement within the programme. If these decrease, it may allude early signs of burnout via an increase in sport devaluation (e.g., Gould et al., 2009; Madigan et al., 2019). Therefore, these findings provide further evidence to support a holistic approach needed to be taken in sporting hockey pathways. Moreover, it would be prudent for sporting pathways to consider male and female differences when evaluating the availability and effectiveness of social support in sporting pathways.

Study Limitations and Future Directions

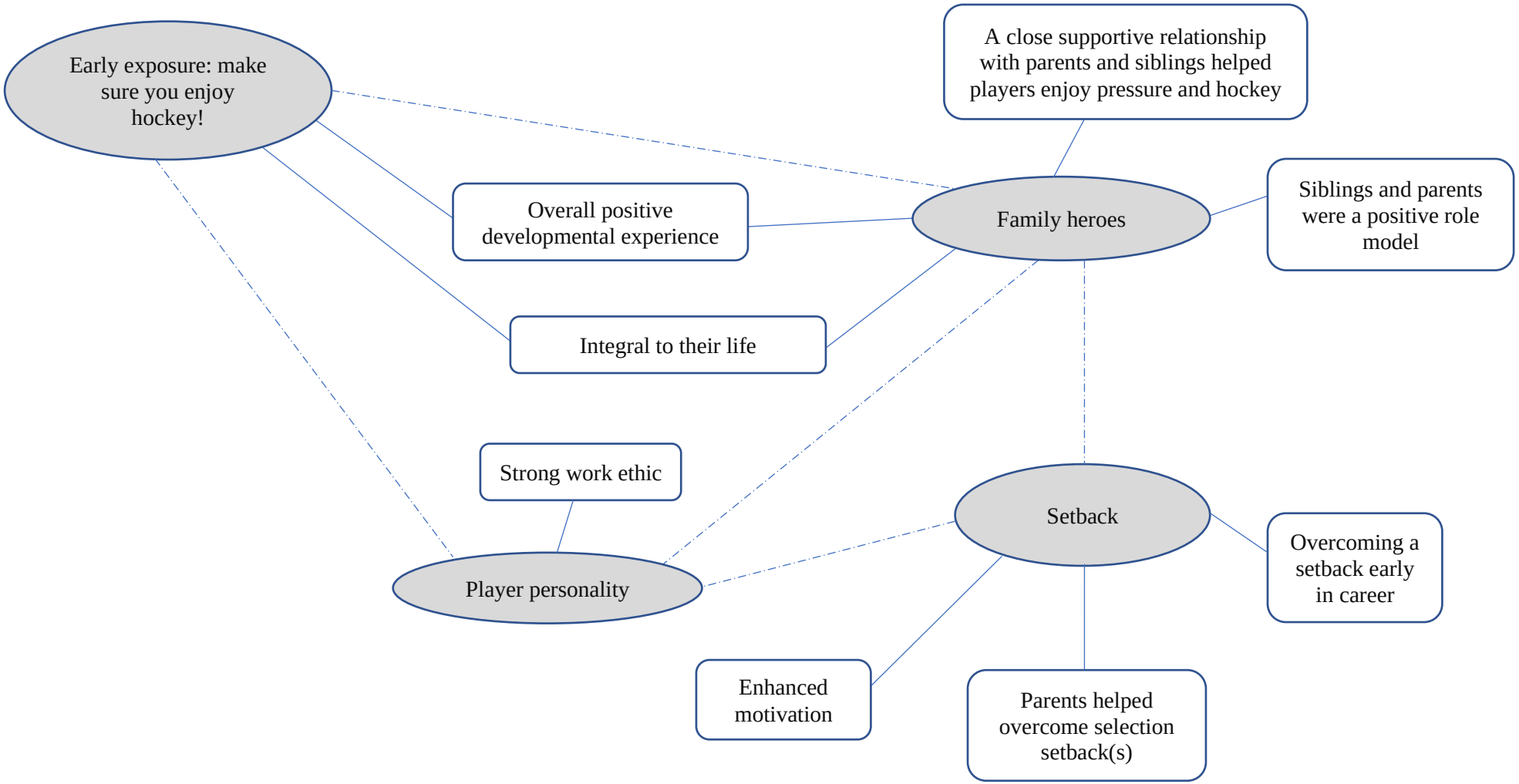
Firstly, whilst a retrospective design provides a useful and holistic investigation into psychosocial factors that were important within the development of male and female players, this design does not clearly capture exactly when in development different types of social support may be more beneficial to hockey players' development. Therefore, future research could employ a longitudinal design to capture the changes in these psychosocial factors (i.e., enjoyment, social support, strong work ethic) and how these may interact with overcoming a setback within their development. Secondly, whilst a deductive-inductive approach was most appropriate to this investigation, taking a deductive approach may have limited the themes generated in comparison to using an unstructured interview. Moreover, other qualitative approaches such as ethnography could provide an even greater depth when interpretating the data collected. Future talent development research could prospectively examine the developmental journeys of hockey players whilst considering using additional qualitative methods (e.g., participant observation). The prospective nature in design and additional qualitative methods would overcome potential recall bias from a retrospective design whilst providing a richer

insight into the factors that can contribute to an effective talent development environment in hockey.

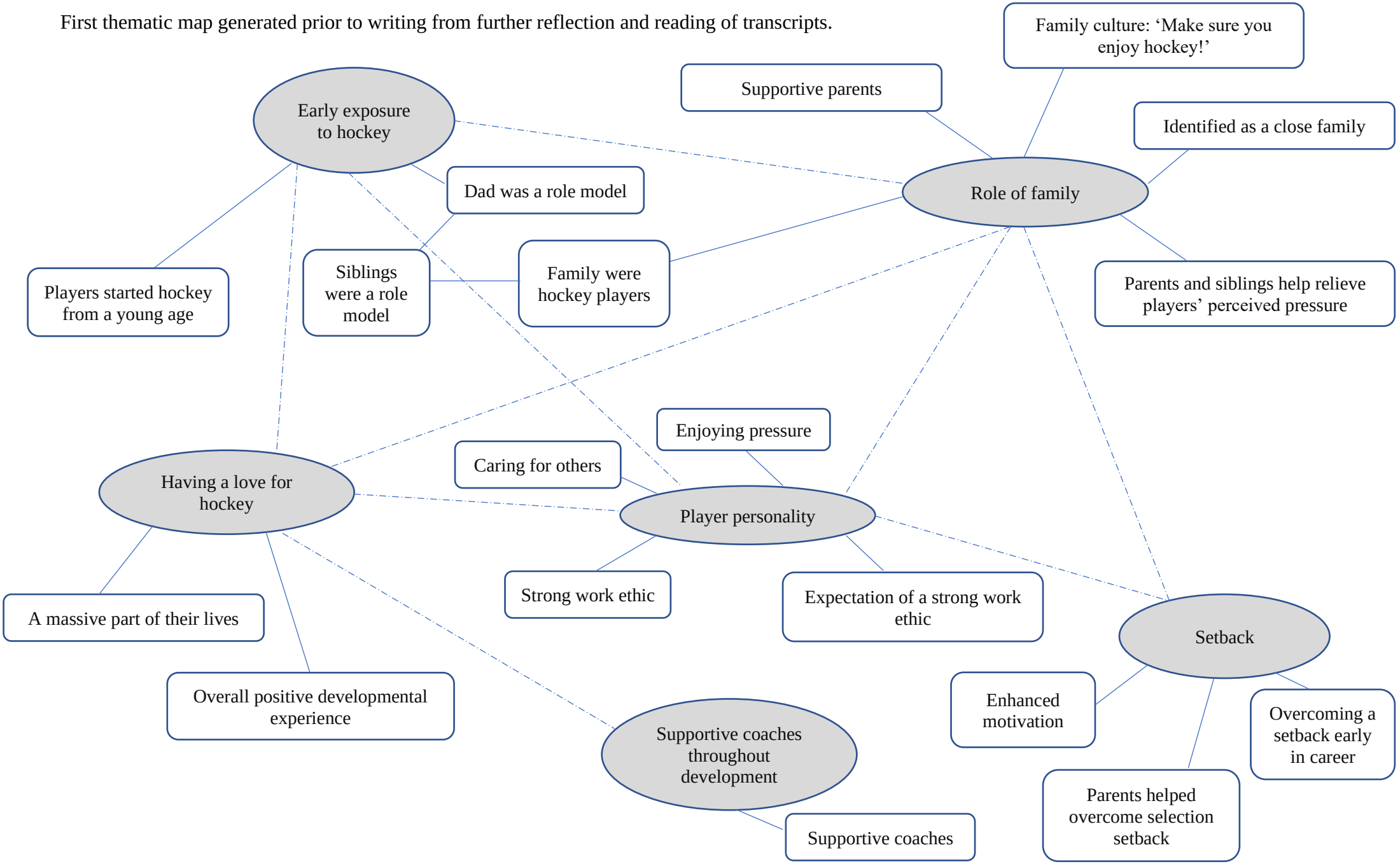
Conclusion

By adulthood, a player is likely to have developed a strong work ethic, a pure enjoyment for hockey, experienced overcoming a major a setback, and rely upon a close supportive network, to help navigate and overcome the challenges needed to play international hockey. Nuanced differences occurred with the type of social support reported by players. Male players reported having benefited from receiving informational support, whilst female players reported having benefited from receiving tangible support. Taken together talent programmes could offer more individualised social support for male and female players, to promote long term engagement through the creation of a more effective talent development environment.

Appendix 1.
Second thematic map generated prior to writing from further reflection and reading of transcripts.



First thematic map generated prior to writing from further reflection and reading of transcripts.



Chapter 3: Multidimensional Characteristics that Predicted the Progression of Male and Female Hockey Players

Abstract

Developing technical skills and psychosocial characteristics in athletes are important to facilitate progression within an elite talent pathway (Baker et al., 2017). Whilst studies have highlighted multidimensional characteristics may discriminate between higher and lower skilled hockey players (e.g., Elferink-Gemser 2006; Elferink-Gemser, 2007), these studies have investigated a mixed-sample of male and female athletes. These findings are in line with recent talent development reviews (e.g., Baker et al., 2020; Johnston et al., 2017; Gledhill et al., 2017) which suggest the talent development literature has primarily investigated mixed or male-only samples of athletes. Therefore, it is unclear how skill development interacts with psychosocial characteristics during an elite hockey talent pathway especially within female players. The purpose of this study was to use pattern recognition derived models to identify a pattern of important practice and training activities and psychosocial characteristics that underpin progression of male and female players in an elite hockey talent pathway. In total, 41 players (n = 22 male, age, 21.18 $\pm$ 1.94; n = 19 female, age, 21.00 $\pm$ 1.60) volunteered to participate in a retrospective practice and training interview. Of which a sample of male (n = 19, age, 21.26 $\pm$ 2.02) and female players (n = 16, age, 21.06 $\pm$ 1.65) participated in a mixed retrospective prospective design whereby players completed practice and training activities and psychosocial characteristics biannually for two seasons (September 2019 – June 2021).

Overall, relatively important features that predicted the progression of male players occurred during early adulthood, whilst important features that predicted the progression of female players occurred in both adulthood and their early development (i.e., pre-specialisation). At adulthood, progressed male players perceived to have completed more blocked practice during the main season and were better able to cope with setbacks. In contrast, prior to specialisation, progressed female players perceived to have been exposed to less anxiety practice, had a parent that was a hockey player, and were more likely to have attended a private college (at 16 years). During early adulthood, progressed female players were at greater risk of mental illness but perceived their training environment as less psychologically challenging.

Taken together, the present multidimensional retrospective prospective study suggests male players may benefit from a differently structured practice environment during development in comparison to female players. For example, male players may benefit more from a sufficient opportunity to practise skills in a blocked fashion in early adulthood, whilst female players may benefit from practising skills in a varied fashion. Additionally, female players may benefit from having pressure training imbedded later in an elite talent pathway.

Introduction

A purpose of a sport talent pathway is for athletes to develop the skills and characteristics players need to be successful on an international stage. A process that is likely impacted by multidimensional factors (Rees et al., 2016). Talent pathways attempt to accelerate skill development by manipulating the practice environment (e.g., Hodges & Williams, 2012; Rothwell et al., 2020), alongside the development of desirable psychosocial characteristics, needed to cope and thrive within a high-performance environment (e.g., Morgan et al., 2019; Kramers et al., 2022). According to the development model of sport participation (DMSP), players who have had early diversification and late specialisation are likely to progress more rapidly in comparison to players who have had an early specialisation in sport (Côté & Vierimaa, 2014; Côte et al., 2009; Güllich et al., 2021). However, a limitation of this theory is it does not consider how many factors may interact to accelerate skill development. Such as, the variability of practising skills (e.g., Jones et al., 2020; Rothwell et al., 2017); an external focus of attention (e.g., Singh & Wulf, 2022); and optimal challenge (e.g., Guadagnoli et al., 2004) to name a few. Whilst these studies are useful to highlight which factors may be important to accelerate skill development, this literature has primarily examined male athletes (Koopman et al., 2020). Whether female athletes' skill development follows a similar trajectory is not clear because the sport science literature does not always take a multidimensional approach (e.g., practice environment & psychosocial characteristics) and seek to understand male and female differences (Nimphius, 2019).

Currently, there is mixed evidence to support whether early diversification and later specialisation is most effective for skill development in comparison to early specialisation, whereby athletes may accumulate more hours of deliberate practice (Barth et al., 2022). Previous studies have captured retrospective practice activities but did not analyse whether interactions occur between childhood and adulthood practice activities (e.g., Jones et al., 2019). Capturing interactions between childhood and adulthood could be key towards better understanding which practice activities are needed to accelerate skill development. A greater understanding of how early and later practice activities effect skill development is especially important when considering different developmental journeys taken by players. We therefore retrospectively captured the practice activities at childhood, then longitudinally-retrospectively captured practice activities at adulthood. Based upon the suggestions from the DMSP (Côte, 1999), we examined the microstructure of practice, during early development, the year prior to specialisation and the year in which players specialised in their hockey position.

Understanding how the practice environment interacts with psychosocial characteristics is important because the practice environment can impact the development of desirable psychosocial characteristics (Baker et al, 2017). Psychological characteristics are needed to thrive within a high-performance environment (e.g., Blijlevens et al., 2018). Whilst Gledhill et al. (2017), highlights psychosocial factors interact with training behaviour in football, the authors note that female football players were underrepresented and therefore which psychological characteristics interact with a female practice environment is not clear. Moreover, whilst there has been an investigation of an interaction between the development of psychosocial characteristics and the practice environment in athletes (e.g., Thomas & Güllich, 2019), these studies do not necessarily consider talent development holistically by measuring few variables simultaneously. For example, Thomas and Güllich (2019) measured motivation (intrinsic, extrinsic & amotivation) and volume of childhood engagement in coach-led practice and child-led play. Analysing a limited number of variables simultaneously could be considered a limitation (e.g., Jones et al., 2019). To overcome this limitation, recent talent development studies have used non-linear pattern recognition derived models to analyse hundreds of theoretically driven characteristics important in effective talent development (e.g., Güllich et al., 2019; Jones et al., 2019). By using a non-linear analysis, we may begin to capture the relatively important factors that predicted male and female progression within an elite hockey pathway. Consequently, we can advance the talent development literature and inform practice by capturing a holistic pattern of important factors that predicted progression within an elite hockey talent pathway.

Currently, studies have identified multidimensional characteristics that predicted performance or selection in talent programmes in team, individual, and mixed sports (i.e., more than one sport was analysed together). Indeed, these studies have examined either a male or mixed (male & female) sample of athletes. To our knowledge, no study has captured multidimensional (psychosocial & practice environment) characteristics that predicted the progression of male and female hockey players in an elite hockey talent pathway. The aim of this study was twofold: 1) to separately investigate the multidimensional characteristics that predicted the progression within elite male and female hockey players; 2) with a retrospective prospective design, we hope to build upon prior retrospective research by analysing practice and training history alongside current practice activities, in addition to psychosocial characteristics. In doing so, we hope to further advance the talent development literature by providing a pattern of relatively important multidimensional characteristics that predicted progression in male and female players. Ultimately, a pattern of relatively important

multidimensional factors will help inform the structure and effective development of elite talent pathways.

Method

Players' practice and training history and psychosocial characteristics were collected from a highly structured interview and quantitative survey. Both the interview and survey generated quantitative data. Practice history and psychosocial data were collected retrospectively using a mixed retrospective prospective design. Players' practice history was recalled from age 6 years whilst psychosocial characteristics and recent practice history were collected from 18 years. Recent practice history was collected retrospective-prospectively for three subsequent timepoints, separated by 6 monthly intervals. Psychosocial characteristics and recent practice history were captured between March 2020 and June 2021. Quantitative data that captured players' psychosocial characteristics and recent practice and training history were analysed both separately and together using pattern recognition analysis.

Participants

Following ethical approval from the Ethics Committee at the School of Sport, Health, and Exercise Sciences at Bangor University (November 2018), a total of 61 U23 Great Britain Hockey Elite Development programme (GB EDP) players (31 female and 30 male) volunteered to participate. Prior to commencement of data collection, 20 players (12 female, 8 males) either: withdrew from the study; were deselected from the programme; or did not complete all aspects of the data collection. In total, 41 male (n = 22, age, 21.18 $\pm$ 1.94) and female players (n = 19, age, 21.00 $\pm$ 1.60) participated in this retrospective-prospective study. Included players trained and competed as an outfield (n = 38) or goalkeeper (n = 4). Female EDP players were classified as either "progressed" (n = 10) or "non-progressed" (n = 9) and male EDP players were classified as either "progressed" (n = 8) or "non-progressed" (n = 14). Following the arrival of the COVID-19 pandemic, formal selections were postponed. Therefore, players were classified as either "progressed" or "non-progressed" with the best available definitions during the time of a global pandemic. More demographic detail of progressed and non-progressed players can be found in Table 1.

Table 1

Description of age between the progressed (*n* = 18) and non-progressed (*n* = 23) players.

	Progressed		**Non-progressed**	
	M	**F**	**M**	**F**
Age (years)	21.9 *(± 2.3 SD)*	21.1 *(± 1.7 SD)*	20.8 *(± 1.7 SD)*	20.9 *(± 1.5 SD)*
Age selected for EDP	18.5 *(± 1.5 SD)*	18.4 *(± 1.2 SD)*	18.1 *(± 1.2 SD)*	19.0 *(± 1.2 SD)*
Age of Senior League debut (years)	17.0 *(± 2.8 SD)*	16.7 *(± 2.0 SD)*	15.9 *(± 1.4 SD)*	16.3 *(± 1.3 SD)*
Age at specialisation (years)	14.8 *(± 1.0 SD)*	14.1 *(± 1.9 SD)*	13.6 *(± 2.1 SD)*	14.7 *(± 1.8 SD)*

Note: Standard deviations are presented in the parentheses.

Measures

The research question and methodology were developed from the Great British Medallist Project (Güllich et al., 2019) and amended over one year following a series of workshops with two senior scientists from English Institute of Sport and GB Hockey. In these workshops, we discussed and developed a rigorous methodology to identify multidimensional characteristics that could inform more effective talent development. Akin to Güllich et al. (2019), the research question suggested a need for a highly structured interview guide and survey to collect psychosocial characteristics and practice and training history using a pattern recognition analysis. The practice history and psychosocial characteristics that were analysed are defined below in Table 2.

Table 2

Definition of the practice and training and psychosocial characteristics.

Demographics
Month of birth: 1 = January; 12 = December
Size of places lived: Population of players' birthplace, primary and secondary school, and university
Number and age of siblings were recorded
Carer sports: The number and type of sports players' carers participated in
Education demographics: private or public primary and secondary school
Employment: number of employment and/or coaching hours players undertook from age 16 years
Involvement in sports
Number of sports: the number of sports played from age 6 years
Hockey practice: the number of self-led and/or coach led hours from age 6 years
Hockey competition hours: the number of competition hours played in hockey from age 6 years
Sport practice: the number of self-led and/or coach led practice hours accumulated in two other major sports
Competition hours in major sports: the combined number of competition hours played from age 6 years in their major sports
Deliberate practice and play: players' perception of the volume of deliberate practice and play within the "sampling" ages (6-12 years) and "specialisation" ages (13-15 years)
Deliberate practice and play: Players' perception of the volume of deliberate practice and play undertook within the "sampling" ages (6-12 years) and "specialisation" ages (13-15 years).
Performance milestones
First selections during GB Hockey's performance pathway: age of players when first selected at "Club", "County", "High pack", "Futures cup", "Home Nations U16, U18, and U21 (NAGS)", "Senior Home Nations", and "GB EDP" level
Challenge: players' perception of challenge at each performance level defined above
Milestones and deselections: players' age when specialised in hockey and the number of times they were formally deselected from the hockey pathway
Physical size: Players' perception of their size in comparison to their teammates at each performance level i.e., "smaller", "equal" or "greater" in physical size.
Injury/Illness record: players reported any major injuries sustained at each performance level (100% equalled no time off and 0% meant they could not train or compete that year)
Microstructure of practice prior to specialisation, when specialised in hockey, and current practice activities
Proportion of deliberate practice and play (see above)
Strength and conditioning hours: number of non-hockey hours dedicated to improvement in fitness and/or recovery
Mental skills and vicarious experiences: players' perception of the number of hours spent watching hockey and/or using visual imagery techniques
Structure of practice: players' perception of the proportion of time spent in blocked, serial, and random practice and how constant and varied these practice types were
Context specificity and anxiety specificity: players' perception of the proportion of time spent in practice that mimicked competition and simulated pressured conditions
Individualised coach-led practice: players' perception of the proportion of time spent 1:1 with a coach

Table 2 continued.

Technical, tactical, and psychological challenge: players' perception of how difficult it was to improve a skill (technical); know what to do in certain situations during the practice (tactical), and cope under pressure (psychological) challenge
Focus and nature of attention: players' proportional perception of time spent using an internal and external focus of attention and whether they practiced skills in parts
Feedback: players' proportional perception of time spent receiving feedback from coaching staff
Proportion of constraints, prescriptive, and player led practice: players' proportional perception of time spent in constraints (e.g., reduced sized pitch), prescriptive (e.g., demonstrations & instructions), and self-led practice (e.g., organisation of their own games and/or drills)
Psychosocial characteristics
Life experiences:
Environment of expectation and achievement: "My family were high achievers. My family expected me to achieve high standards."
Strong work ethic "My family worked hard to achieve things that were important to them. My family were very hard working."
Highly competitive environment: "People in my family competed against one another a lot of the time. My family members were very competitive with each other."
Outcome focus: "My family expected me to outperform my opponents.
My family expected me to beat other people."
Mastery focus: "My family expected me to perform to the best of my ability.
My family expected me to show clear personal improvements."
Career turning point: "I experienced a moment within my sport that inspired me.
Finding sport was a turning point in my life."
Positive critical sport event: "I have experienced a significant event that made me more determined to succeed in my sport. I have experienced a significant turning point in my sporting career that enhanced my focus."
Sense of Coherence (comprehensibility): "In the past 10 years your life has been completely consistent and clear. Your life in the future will probably be completely consistent and clear."
Manageability: "When you think of the difficulties you are likely to face in important aspects of your life, do you have the feeling that you will always succeed in overcoming difficulties. You very often have feelings that you are not sure you can keep under control."
Meaningfulness: "You very often have the feeling that you do not really care what goes on around you. Doing the thing you do every day is a source of deep pleasure and satisfaction."
Relationality: "It has never happened to you in the past that you were surprised by the behaviour of people whom you though you knew well. It has never happened that people whom you counted on disappointed you."
Career Aspirations: "Over the last 6 months, having a non-sporting career was important to me. Over the last 6 months making a career out of being an athlete was important to me. Over the last 6 months having a dual career of sport and work was important to me."
Personality:
Difficulty with Emotional Expression: "I am often emotional without understanding why. People tell me to describe my feelings more."
Counterphobia: "I am drawn to things I am afraid of. I love how nervous competition makes me feel."
Need to Avoid Failure: "In sport, failure is not an option for me. In competition, just the idea of not winning fills me with dread."
Need to succeed: "I am driven by a need to succeed in my sport. Succeeding in my sport is the only thing that matters to me."

Table 2 continued.

Ruthlessness: “I am willing to be disliked if it means being able to achieve my targets in sport. When it comes to sport, I am ruthless when I need to be.”
Selfishness: “In sport, I put my own interests before the interests of others. When it comes to sport, you have to be selfish.”
Perfectionistic concerns: “During training, I get completely furious if I make mistakes. During competition, I get completely furious if I make mistakes. During training, I get frustrated if I do not fulfil my high expectations. During competition, I get frustrated if I do not fulfil my high expectations.”
Perfectionistic strivings: “I feel that other athletes generally accept lower standards for themselves in sport that I do. I have extremely high goals for myself in sport.”
Socially prescribed perfectionism: “Others criticise everything I do not do perfectly. Others expect my performance to be perfect.”
Obsessiveness: “I cannot live without my sport. I have an almost obsessive feeling for my sport. Something inside me means that I can’t help myself from playing my sport.”
Grandiose Narcissism: “I think I am a special person. I like having authority over people.”
Vulnerable Narcissism: “I am secretly “put out” or annoyed when other people come to me with their troubles, asking for my time and sympathy. I often interpret the remarks of others in a personal way.”
ASD (Empathy) “I frequently find that I don’t know how to keep a conversation going. I find it easy to work out what someone is thinking or feeling just by looking at their face (reversed).”
ASD (Systemising): “It does not upset me if my daily routine is disturbed (reversed). I notice patterns in things all the time.”
Big 5 (Extraversion, Agreeableness, Conscientiousness, Emotional stability and Open to new experiences)
Training and competition behaviour
Outcome Focus: “When playing my sport, I feel successful when I beat other people. When playing my sport, I feel successful when I outperform my opponents.”
Mastery Focus: “When playing my sport, I feel successful when I perform to the best of my ability. When playing my sport, I feel successful when I show clear personal improvements.”
Total Preparation for Competition: “I leave no stone unturned in preparation for competition. I go beyond the norm to prepare for competition.”
Commitment to Training: “I always produce a high quality training session. No matter what is going on in my life, I still turn in a good training session.”
Relative Importance of Sport: “My sport is the most important thing in my life. My sport offers me more than anything else in life (e.g., friends, family, relationships, money).”
Transformational leadership: Players’ perception of coach behaviour
Hockey experiences
Importance of autonomy, relatedness, and competence (e.g.,): “In my sport, I get opportunities to make decisions. In my sport, there are people who I can trust. I am skilled at my sport.”
Mental Toughness: “I am able to use my emotions to perform the way I want to. I consistently overcome adversity.”
Psychological Characteristics of Developing Excellence: Adverse response to failures, Imagery and active preparation, self-directed control and management, perfectionistic tendencies, seeking and using social support, active coping, and clinical indicators.
Self Esteem: “I feel that I have a number of good qualities. I certainly feel useless at times.”
Motivation (Intrinsic, integrated, identified, introjected, external & amotivation): E.g., “Because it gives me pleasure to learn more about my sport. Because participating in a sport is an integral part of my life. Because I have chosen this sport as a way to develop myself. Because I would

Table 2 continued.

feel bad about myself if I did not take the time to do it. Because people I care about would be upset with me if I didn't. I used to have good reasons for doing sports, but now I am asking myself if I should continue."
Relationship with others
Secure: "It is easy for me to become emotionally close to others. I am comfortable depending on them and having them depend on me. I don't worry about being alone or having others not accept me." Fearful: "I am uncomfortable getting close to others. I want emotionally close relationships, but I find it difficult to trust others completely, or to depend on them. I worry that I will be hurt if I allow myself to become too close to others." Preoccupied: "I want to be completely emotionally intimate with others, but I often find that others are reluctant to get as close as I would like. I am uncomfortable being without close relationships, but I sometimes worry that others don't value me as much as I value them." Dismissive: "I am comfortable without close emotional relationships. It is very important to me to feel independent and self-sufficient, and I prefer not to depend on others or have others depend on me."
Coaches and support
Need supportive behaviours (autonomy support, structure & involvement): E.g., "My coaches take into account my individual needs. Give me good advice. Make me feel like I matter to them." Coach athlete relationship (commitment, closeness & complementary): E.g., "I feel committed to my coach. I trust my coach. When I am coached by my coach, I am ready to do my best." Responsiveness: E.g., "My thoughts and feelings are important to my coach." Coaching behaviours (Individual consideration, inspirational motivation, intellectual stimulation, acceptance of group goals, high performance expectations, appropriate role model & contingent reward). E.g., "Recognise that different athletes have different needs. Talk enthusiastically. Get me to rethink the way I do things. Get the team to work together for the same goal. Always expect us to do our best. Always set a good example. Personally praise me when I do outstanding work." Observation: "Pays close attention to what I do. Carefully watches me doing the skills and drills." Effective questioning: "Encourages me to make suggestions on how I can improve my performance. Asks my opinion on how I can improve my performance." Goal setting: "Provides support to help attain my goals." Development and motivational feedback: "Make sure I understand what I need to do to improve. Gives me advice on how to improve my skills." Support from social media: "Tells me when I do a particularly good job. Expresses appreciation when I perform well." Negative Emotional social media: "I get a lot of negative responses on my social media. It freaks me out if my friend/follower number decreases." Social support from coaches (Instrumental, Organisational, Emotional, Esteem & Informational Tangible): E.g., "I need help with something, I could post it on social media and I'd get the help I need. The NGB really cares about my well-being. Provide you with comfort and security. Enhance your self-esteem. Gives you constructive criticism. Help with travel to training and matches/ competitions."

Note: Major sports were chosen by the players. These sports were considered as their chosen sports prior to or alongside their involvement in hockey during development. For the psychosocial features players rated "Strongly Disagree", "Somewhat Disagree", "Neither Agree nor Disagree", "Somewhat Agree", or "Strongly Agree."

Practice and training. Capturing practice activates across developmental stages enabled us to have a better understanding of the relative importance of practice activities during different developmental stages. The retrospective practice and training interview comprised four sections. Specifically, demographics, early sporting experience, developmental milestones, and microstructure of practice. The microstructure of practice was obtained the year prior to specialising in hockey (i.e., pre-specialisation) and the year that players specialised in hockey (i.e., specialisation). The retrospective practice history interview practice and training interviews were conducted in-person at the players' chosen location. Players lived across the UK in England, Scotland, and Wales. Additionally, the microstructure of practice was also collected as part of the retrospective prospective design. The practice activities and psychosocial data were collected biannually (i.e., investment). With the arrival of the Global COVID-19 Pandemic and the introduction of national lockdowns from March 2020, the retrospective prospective element (i.e., practice and training interviews and psychosocial survey) was collected electronically and over the telephone). See Table 1 for a breakdown of macrostructure and microstructure of practice activities collected.

Psychosocial characteristics. Based upon the findings from the Great British Medallist Project (Hardy et al., 2017), two psychosocial surveys were created as part of the Pathway2Podium project from existing validated questionnaires. The first survey (Athlete Psychosocial Survey) examined 28 psychosocial characteristics relating to early developmental experiences. Specifically, these psychosocial characteristics were categorised into three sections athlete life experiences, personality, and training behaviour. The second psychosocial survey (Prospective Athlete Survey) examined 15 additional psychosocial characteristics regarding players' perceptions of their coach and work staff that support them, their experiences within hockey, and their life experiences. With the arrival of the Global COVID-19 Pandemic and the introduction of national lockdowns from March 2020, the Prospective Athlete Survey was completed electronically by the player. See Table 2 for the psychosocial characteristics measured.

Procedure

The Pathway2Podium project was introduced to male and female EDP players at their respective national training camps in Lilleshall, UK. Players read an information leaflet and were given the opportunity to ask questions about the project. It was made clear that the project would not influence any selection decisions at any point. Once the consent form was signed,

61 players completed the Athlete Psychosocial Survey (baseline). Players were then later invited to complete the 90-minute retrospective practice and training interview between October 2019–December 2019. The 30-minute prospective practice and 30-minute training interview were collected every 6 months over a 15-month period between March 2020–June 2021. There were three times points in total (2019/20 Main season, 2020/21 pre-season & 2020/21 Main season). Across all time points 35 players (16 females, 19 males) completed a microstructure of practice interview and 29 players (16 females, 13 males) completed a psychosocial survey. See Figure 1.

Reliability and Validity

The highly structured quantitative interview has been previously used to gather practice history in elite and super-elite populations (e.g., Güllich et al., 2019; Jones et al; 2020). Additionally, initial concurrent and convergent validity of the Athlete Psychosocial Survey was gained in a sample of high and low-level hockey players (Langham-Walsh, 2021). To aid the rigor within data collection, the lead researcher (ED) conducted pilot interviews (n=4) with the outcome of the pilot interviews, procedure, definitions, and data collected discussed with two experts in the field.

Data Analysis

In line with similar studies (e.g., Owen et al., 2022), bayesian pattern recognition was performed using R, a programming language (R Core Development, 2021) to identify a pattern of factors that discriminated players into groups (i.e., progressed, or non-progressed). Practice and training and psychosocial factors were first analysed in silo before being combined within a multidisciplinary model. One reason was to aid the interpretation of the multidimensional model. For example, if practice and training features were deemed important in more than one model, it may future increase the confidence in the model whilst further alluding to which psychosocial features may be interacting during development. See Table 1 and 2 for an overview of the practice and training (n = 78) and psychosocial features (n = 195) evaluated in the pattern recognition analysis. The class (progression) was defined as “progressed” (i.e., players had trained at least once with the Senior GB squad from January 2021). Players who had trained only within the EDP programmed were grouped as “non-progressed.” Akin to Anderson et al. (2020), factors (attributes) were normalized between 0 and 1 to allow for meaningful comparisons between multidimensional variables. Data was manipulated using R packages: readxl (Wickham, et al., 2019); dpylr (Wickham, et al., 2015); tidyverse (Wickham,

et al., 2019); and stringr (Wickham & Wickham, 2019). Within both stages of the pattern recognition analysis, the following R packages were used: rJava (Urbanek, 2019); rebus (Cotton, 2017); rWeka (Hornik et al., 2009); and tree (Ripley, 2021; Henry & Wickham, 2018).

Feature Selection

Feature selection uses machine learning algorithms to build a model of discriminatory variables that best predicts instances (players) into a predefined class. Four different feature selection algorithms were used: correlation attribute evaluator (Hall, 1999), relief F attribute evaluator (Kira & Rendell, 1992), gain ratio attribute evaluator (Gnanambal et al., 2018), and info gain attribute evaluator (Gnanambal et al., 2018). These four algorithms rank the importance of attributes and then ranked 20 attributes that best discriminated between the class (relatively progressed and non-progressed players). At least 2/4 feature selection algorithms agreed that an attribute was important to be included within the model. Practice and training and psychosocial data collected were analysed in silos and then together. This was to examine the relative importance of attributes within each discipline, prior to analysing the relative importance of attributes across disciplines. Specifically, models analysed: practice and training history (3.1.1 & 3.2.1); practice and training between 2019/20 and 2020/21 season (3.1.2 & 3.2.2); psychosocial characteristics (3.1.3 & 3.2.3); and a multidisciplinary model (3.1.4 & 3.2.4). In total, 8 feature selection models were conducted (4 female, 4 male).

Classification

Classification is the evaluation of a feature selection model. Classification algorithms produce a percentage accuracy of identified instances (i.e., players) that are placed correctly into the predefined class. Four classification algorithms were used to evaluate the feature selection model: naïve bayes (John & Langley, 1995), J48 decision tree (Quinlan, 1993), Support Vector Machine (Keerthi et al., 2001), and K-nearest neighbour (Aha et al., 1991). Attributes identified within the feature selection model were used by the classification algorithms to predict an instance (player) into a class (progressed or non-progressed). Leave-one-out method was used during classification to reduce the likelihood of the model overfitting (Vehtari, 2017). A percentage accuracy was then generated based on the correctly classified instances.

Results

Male Players

Table 3 presents an overall summary of the 4 models created by feature selection, along with each model's area under the curve. All models had at between 3 to 5 features selected. The table displays the features selected with the agreement of all 4, 3 and 2 algorithms.

Table 3. An overall summary of the pattern recognition models that predicted progressed male players.

	Male player pattern recognition models														
	Practice and training						**Psychosocial characteristics**			**Multidisciplinary and retrospective-longitudinal model**					
Player models:	Practice History			Practice and training between 2019/20 and 2020/21 season			Psychosocial characteristics between 2019/20 and 2020/21 season			Practice history with practice experienced and psychosocial characteristics present, between 2019/20 and 2020/21 season.					
Time:	During development	Year prior to specialisation	Year of specialisation in hockey position	Main season 19/20	Pre-season 20/21	Main season 20/21	Main season 19/20	Pre-season 20/21	Main season 20/21	Year prior to specialisation	Year of specialis-ation in hockey position	Main season 19/20	Pre-season 20/21	Main season 20/21	
4 algorithms in agreement:	Significant moment at club	Blocked-varied practice (%)			Number of competition hours				Adverse response to failure				Serial practice (%)	Adverse response to failure	
3 algorithms in agreement:		Blocked-constant practice				Serial-varied practice (number)		Perception of coach observation				Blocked practice (%)		Manageability	
2 algorithms in agreement:		Blocked-varied practice (number)	Blocked varied (number)	Random practice (%)		Study hours Perceived psychological difficulty of practice		Self-directed control and management				Instrumental support			
Area under the curve (ROC):	0.70			0.55			0.70			0.67					

Practice and training history in male players. Perception of team skill-based training experiences differed between progressed and non-progressed male players (Table 4). During the year prior to specialisation, progressed players perceived to have experienced less variability during blocked practice in comparison to non-progressed players. Typically, one aspect (speed, direction and/or height) varied. During a typical week in the year of specialisation, the variability of blocked practice was greater. Typically, two aspects (speed, direction and/or height) varied. However, non-progressed players still perceived to have had a greater variability in blocked practice. Additionally, progressed players were more likely to report having experienced a significant moment during their club environment.

Table 4

Mean score of selected attributes that predicted group membership of progressed and non-progressed male players

Feature selection attributes	Progressed	Non-progressed
Year prior to specialisation:		
Proportion of blocked varied (%)	23.1	55.0
Proportion of blocked constant (%)	64.4	45.0
Blocked varied number[1]	1.0	2.0
Year of specialisation in position:		
Block varied number[1]	2.1	2.6
Demographic:		
Significant moment in club	8/8	8/14

[1] Varied number represents the number of aspects within a skill that was deliberately varied during practice (i.e., speed, direction, and/or height of the ball).

The predictive model could classify between the two groups with a mean of 0.70 area under the curve and 80% classification accuracy (Table 5). A mean sensitivity score of 0.90 suggests the model is 90% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.62 suggests the model is 62% likely to correctly assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 5

Evaluating the performance of the predictive model of selected attributes

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	81.82	0.86	0.75	0.79
Support Vector Machine	72.73	0.93	0.37	0.65
K nearest neighbour	72.73	0.86	0.50	0.54
J48 decision tree	90.91	0.93	0.87	0.81
All classifiers	**79.55**	**0.90**	**0.62**	**0.70**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

Practice and training between 2019/20 and 2020/21 season in male players. Perception of team skill-based training experiences differed between progressed and non-progressed male players over the 2019/20 and 2020/21 season (Table 6). During the 2019/20 main season (i.e., prior to COVID-19), progressed male players reported having perceived less random practice in comparison to non-progressed players. In the pre-season of the 2020/21 season (i.e., during COVID-19), progressed players reported having less exposure to competition. During the 2020/21 main season, progressed players reported serial practice was considered more varied (i.e., speed, direction, and/or height of the ball), but reported studying less hours per week and perceived less psychological difficulty of the practice in comparison to non-progressed players.

Table 6

Mean score of selected attributes that predicted group membership of progressed and non-progressed male players

Feature selection attributes	**Progressed**	**Non-progressed**
Main season (2019/20) [1]**:**		
Proportion of random practice (%)	54.0	69.0
Pre-season (2020/21):		
Hours of competition	0.9	1.4
Main season (2020/21):		
Serial varied number[2]	2.4	1.5

Duration of study (hours)	8.5	19.0
Psychological difficulty of practice	3.0	5.0

[1] Data was collected prior to COVID 19. [2]Varied number represents the number of aspects within a skill that was deliberately varied during practice (i.e., speed, direction, and/or height of the ball).

The predictive model could classify between the two groups with a mean of 0.55 area under the curve and 68% classification accuracy (Table 7). A mean sensitivity score of 0.86 suggests the model is 86% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.40 suggests the model is 40% likely to correctly assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 7

Evaluating the performance of the predictive model of selected attributes

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	68.42	0.75	0.57	0.62
Support Vector Machine	68.42	0.92	0.29	0.60
K nearest neighbour	68.42	0.92	0.29	0.61
J48 decision tree	68.42	0.84	0.43	0.36
All classifiers	**68.42**	**0.86**	**0.40**	**0.55**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

Psychosocial characteristics of male players. During the 2020/21 pre-season progressed players more strongly agreed to the statements “My coach pays close attention to what I do” and “My coach carefully watches me doing the skills and drills.” Additionally, progressed players reported higher levels of self-control by more strongly disagreeing with the statement “I do certain things that are bad for me if players are fun” and more strongly agreeing with the statement “I am good at resisting temptation” in comparison to non-progressed players. During the 2020/21 main season progressed players reported having a weaker adverse

response to failure (Table 8). Specifically, players reported to disagree more strongly with the statements "Even minor setbacks disturb my focus" and "I often keep thinking about the mistakes I have made and let this interfere with my performance."

Table 8

Mean score of selected attributes that predicted group membership of progressed and non-progressed male players

Feature selection attributes	**Progressed**	**Non-progressed**
Pre-season (2020/21):		
Perceptions of coach: observation	4.4	3.7
Self-directed control and management	4.2	3.1
Main season (2020/21):		
Adverse response to failure	1.5	3.4

The predictive model could classify between the two groups with a mean of 0.70 area under the curve and 85% classification accuracy (Table 9). A mean sensitivity score of 1.00 suggests the model is 100% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.55 suggests the model is 55% likely to correctly assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 9

Evaluating the performance of the predictive model of selected attributes

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	84.62	1.00	0.60	0.88
Support Vector Machine	84.62	1.00	0.60	0.80
K nearest neighbour	84.62	1.00	0.60	0.70
J48 decision tree	76.92	1.00	0.40	0.40
All classifiers	**82.69**	**1.00**	**0.55**	**0.70**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

A multidisciplinary model in male players. There were multidimensional differences between progressed and non-progressed players during development (Table 10). All attributes identified as most important to predict group progressed players occurred whilst players were training within the GB EDP. Progressed players perceived to have experienced more blocked practice and less instrumental support via social media during the 2019/20 main season, in comparison to non-progressed players. During the 2020/21 pre-season, progressed players perceived to have experienced less serial practice in comparison to non-progressed players. During the 2020/21 main season, progressed players reported a weaker adverse response to failure. Specifically, players reported to disagree more strongly with the statements "Even minor setbacks disturb my focus" and "I often keep thinking about the mistakes I have made and let this interfere with my performance." Alongside a weaker adverse response to failure, progressed players reported a stronger sense of manageability within their lives, by agreeing more strongly to "You very often have feelings that you are not sure you can keep under control" and more strongly disagreeing with "You very often have the feeling that you do not really care what goes on around you."

Table 10

Mean score of selected attributes that predicted group membership of progressed and non-progressed male players

Feature selection attributes	Progressed	Non-progressed
Main season (2019/20)		
Proportion of blocked practice (%)	22.7	8.8
Instrumental support	2.0	2.5
Pre-season (2020/21):		
Proportion of serial practice (%)	21.0	38.8
Main season (2020/21):		
Adverse response to failure	1.5	3.4
Manageability	4.6	3.8

The predictive model could classify between the two groups with a mean of 0.67 area under the curve and 79% classification accuracy (Table 11). A mean sensitivity score of 0.97 suggests the model is 97% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.50 suggests the model is 50% likely to correctly assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 11

Evaluating the performance of the predictive model of selected attributes.

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	92.31	1.00	0.80	0.80
Support Vector Machine	84.62	1.00	0.60	0.80
K nearest neighbour	76.92	1.00	0.40	0.88
J48 decision tree	61.54	0.88	0.20	0.19
All classifiers	**78.85**	**0.97**	**0.50**	**0.67**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

Female Players

Table 12 presents an overall summary of the 4 models created by feature selection, along with each model's area under the curve. All models had at between 3 to 5 features selected. The table displays the features selected with the agreement of all 4, 3 and 2 algorithms.

Table 12
An overall summary of the pattern recognition models that predicted progressed female players

	Female player pattern recognition models														
	Practice and training						**Psychosocial characteristics**				**Multidisciplinary and retrospective-longitudinal model**				
Player models:	Practice History			Practice and training between 2019/20 and 2020/21 season			Psychosocial characteristics between 2019/20 and 2020/21 season				Practice history with practice experienced and psychosocial characteristics present, between 2019/20 and 2020/21 season.				
Time:	During development	Year prior to specialisation	Year of specialisation in hockey position	Main season 19/20	Pre-season 20/21	Main season 20/21	During development	Main season 19/20	Pre-season 20/21	Main season 20/21	During development	Year prior to specialisation	Year of specialisation in hockey position	Main season 19/20	Pre-season 20/21	Main season 20/21
4 algorithms in agreement:	Parent hockey player	Anxiety specific practice (%) Anxiety difficulty			Serial constant practice (%)		Empathy			Career aspirations		Anxiety specific practice (%)			Serial constant practice (%)	
3 algorithms in agreement:		Mental skills			Serial varied practice (%)		Extraversion		Perceptions of coach: Individual consideration			Mental skills			Serial varied practice (%)	Clinical indicators
2 algorithms in agreement:		Challenge during execution of blocked practice Context specific practice (%)	Context specific practice (%)		Mental fatigue	Number of competition hours Random decision-making challenge	Dismissive attachment				College type Parent hockey player			Comprehensibility Psychological challenge	Mental skills	Employment hours
Area under the curve (ROC):	0.80			0.76			0.87				0.83					

Practice and training history in female players. Perception of practice history differed between progressed and non-progressed female players (Table 13). During a typical week prior to specialisation, progressed female players perceived to have experienced less context specific and anxiety practice with progressed players having perceived less challenging during anxiety and blocked practice. Progressed players were less likely to have engaged in mental skills but more likely to have had a parent who was a hockey player. During a typical week in the year of specialisation, progressed players still reported to have experienced less context specific practice in comparison to non-progressed players.

Table 13

Mean score of selected attributes that predicted group membership of progressed and non-progressed female players

Feature selection attributes	Progressed	Non-progressed
Year prior to specialisation:		
Proportion of anxiety training (%)	25.5	57.2
Proportion of context specific practice (%)	41.0	59.4
Perceived challenge in anxiety training[1]	4.0	6.3
Perceived challenge of blocked practice[2]	3.3	5.7
Mental skills[3]	2.0	1.6
Year of specialisation in position:		
Proportion of context specific practice (%)	47.0	63.8
Demographic:		
Parent was hockey player[4]	7/10	1/9

[1] Challenge score was measured on 1-10 Likert scale (1 = not at all challenge, 10 = maximally challenging). [2] Total number of players who had attribute (e.g., 0/10 progressed players engaged in mental skills training the year prior to specialisation). [3]Data was coded as 1 = players reported reflecting on previous training or competition experiences 2 = players reported that players did not reflect on previous training experiences or competition. [4] At least one parent was a hockey player.

The predictive model could classify between the two groups with a mean of 0.80 area under the curve and 79% classification accuracy (Table 14). A mean sensitivity score of 0.81 suggests the model is 81% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.78 suggests the model is 78% likely to correctly

assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 14

Evaluating the performance of the predictive model of selected attributes

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	89.47	0.89	0.90	0.91
Support Vector Machine	84.21	0.89	0.80	0.84
K nearest neighbour	73.68	0.78	0.70	0.84
J48 decision tree	68.42	0.67	0.70	0.60
All classifiers	**78.95**	**0.81**	**0.78**	**0.80**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

Practice experiences between 2019-20 and 2020/21 season in female players. Perception of team practice experiences differed between female progressed and non-progressed players over the 2019/20 and 2020/21 season (Table 15). Within the 2020/21 pre-season season (i.e., prior to COVID-19), progressed female players reported more variability during serial-varied practice and overall, less serial constant practice. Following training sessions, progressed players reported feeling less mentally fatigued. During the 2020/21 main season, progressed players reported decision making during random practice less challenging in comparison to non-progressed players. Additionally, 2/7 non-progressed players reported exposure to competition during this phase, whereas 0/9 relatively progressed players did not.

Table 15

Mean score of selected attributes that predicted group membership of progressed and non-progressed female players.

Feature selection attributes	**Progressed**	**Non-progressed**
Pre-season (2020/21):		
Proportion of serial constant (%)	48.9	69.3
Proportion of serial varied (%)	51.0	31.0

Mental fatigue[5]	4.2	5.9
Main season (2020/21):		
Random decision making challenge[6]	5.2	6.4
Exposure to hockey competition[7]	2/7	0/9

[5]Mental fatigue was measured on a 1-10 Likert scale (1 = not at all, 10 = maximally mentally fatiguing).
[6]Random decision making challenge was measured on a 1-10 Likert scale. Players were asked to rate the challenge to make decisions during random practice (1 = not at all, 10 = maximally challenging).
[7]Exposure to hockey competition was impacted by National and International lockdowns due to the COVID-19 pandemic.

The predictive model could classify between the two groups with a mean of 0.76 area under the curve and 73% classification accuracy (Table 16). A mean sensitivity score of 0.61 suggests the model is 61% likely to correctly assign progressed players into the progressed group. A mean specificity score of 0.84 suggests the model is 84% likely to correctly assign non-progressed players into to a non-progressed group, based on the features selected in this model.

Table 16

Evaluating the performance of the predictive model of selected attributes

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	81.25	0.71	0.89	0.84
Support Vector Machine	81.25	0.71	0.89	0.80
K nearest neighbour	68.75	0.43	0.89	0.84
J48 decision tree	62.50	0.57	0.67	0.54
All classifiers	**73.44**	**0.61**	**0.84**	**0.76**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

Psychosocial characteristics of female players. Psychosocial characteristics differed between progressed and non-progressed players (Table 17). Progressed female players reported a weaker tendency towards forming dismissive attachments with others. Specifically, players agreed less strongly with the statements "I am comfortable without close emotional relationships. It is very important to me to feel independent and self-sufficient, and I prefer not to depend on others or have others depend on me" in comparison to non-progressed players. Additionally, progressed players reported weaker characteristics of empathy. Specifically, players agreed more strongly with "I frequently find that I don't know how to keep a conversation going" and disagreed more strongly with "I find it easy to work out what someone is thinking or feeling just by looking at their face." Alongside reporting less empathetic characteristics, progressed players reported stronger levels of extraversion by agreeing more strongly to the statement "I see myself as extraverted, enthusiastic" and more strongly disagreed with the statement "I see myself as reserved, quiet" in comparison to non-progressed players. Progressed players likewise reported a stronger transformative leadership characteristic (individual consideration), in the coaches and staff who work with them by agreeing more strongly to the statements "coaches recognise that different athletes have different needs" and coaches "help team members develop their strengths." During the 2020/21 main-season, progressed players reported a stronger desire towards having a dual career (i.e., career in hockey and a non-hockey career), whereas non-progressed players had a stronger desire towards a non-hockey related career.

Table 17

Mean score of selected attributes that predicted group membership of progressed and non-progressed female players

Feature selection attributes	Progressed	Non-progressed
During development		
Dismissive attachment	3.2	3.6
Extraversion	9.1	6.6
Empathy	2.6	4.6

Pre-season (2020/21):		
Perceptions of coach: Individual consideration	4.3	3.5
Main season (2020/21):		
Career aspirations	1.0	1.6

The predictive model could classify between the two groups with a mean of 0.87 area under the curve and 87% classification accuracy (Table 18). A mean sensitivity score of 0.65 suggests the model is 65% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.98 suggests the model is 98% likely to correctly assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 18

Evaluating the performance of the predictive model of selected attributes.

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	93.33	1.00	0.90	1.00
Support Vector Machine	93.33	0.80	1.00	0.90
K nearest neighbour	73.33	0.20	1.00	0.98
J48 decision tree	86.67	0.60	1.00	0.60
All classifiers	**86.67**	**0.65**	**0.98**	**0.87**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

A multidimensional model in female players. There were multidimensional differences between progressed and non-progressed players across development (Table 19). Progressed players reported less anxiety practice and perceived having engaged less in mental skills, the year prior specialisation in hockey. Moreover, progressed players were more likely to have had a parent who played hockey and were more likely to attend a college that required

tuition fees at 16 years. During the 2019/20 season, progressed players perceived their present and future life is less comprehensible in comparison to non-progressed athletes. Specifically, progressed players more strongly disagreed with the statements "In the past years your life has been completely consistent and clear" and "Your life in the future will probably be completely consistent and clear." However, progressed players perceived the training as psychological challenge less challenging in comparison to non-progressed players. During the 2020/21 preseason, progressed players reported to have experienced a greater volume of serial varied practice and less serial constant practice in comparison to non-progressed players. Progressed players however were more likely to have engaged in mental skills in comparison to the non-progressed players. In the 2020/21 main season, progressed players were more likely to report clinical indicators of mental illness by more strongly agreeing to the statements "I socialise with my teammates much less than I used to" and "If something unexpected happens I find it really hard to adapt" in comparison to non-progressed players. Progressed players reported working more hours in employment (e.g., coaching) in comparison to non-progressed players.

Table 19

Mean score of selected attributes that predicted group membership of progressed and non-progressed female players

Feature selection attributes	Progressed	Non-progressed
Year prior to specialisation:		
Proportion of anxiety training (%)	25.5	57.2
Mental skills[3]	2	1.6
Demographic:		
Parent was hockey player[2]	7/10	1/9
College type (16 years)[8]	8/10	4/9
Main season (2019/20)		
Comprehensibility	1.8	2.9
Perceived difficulty of anxiety practice[1]	2.1	5.6
Pre-season (2020/21):		
Proportion of serial constant (%)	48.8	77.0
Proportion of serial varied (%)	51.1	23.0
Mental skills[3]	0.29	1.8

Main season (2020/21):		
Clinical Indicators	3.0	1.8
Employment[9]	3/9	5/6

[8]Players paid tuition fees to attend a non-state funded College. [9]Player was employed.

The predictive model could classify between the two groups with a mean of 0.85 area under the curve and 85% classification accuracy (Table 20). A mean sensitivity score of 0.75 suggests the model is 75% likely to correctly assign progressed players into the progressed player group. A mean specificity score of 0.91 suggests the model is 91% likely to correctly assign non-progressed players into to the non-progressed group, based on the features selected in this model.

Table 20

Evaluating the performance of the predictive model of selected attributes.

Classifier	Classification accuracy (%)	Sensitivity	Specificity	Area under the curve
Naive Bayes	78.57	0.60	0.89	0.78
Support Vector Machine	92.86	0.80	1.00	0.90
K nearest neighbour	92.86	0.80	1.00	0.98
J48 decision tree	57.14	0.80	0.78	0.64
All classifiers	**80.36**	**0.75**	**0.91**	**0.83**

Sensitivity was calculated as 1 – false positive = true positive score. Specificity was calculated as 1 – false negative = true negative score.

Discussion

The purpose of the study was to further advance the talent development literature by 1) provide a pattern of relatively important multidimensional characteristics that predicted progression within male and female hockey players, and 2) build upon prior retrospective talent development research by analysing practice and training history alongside current practice activities and psychosocial characteristics. Analysing male and female players separately revealed multidimensional developmental differences. Overall, relatively important features that predicted progression of male players occurred within their current practice activities (during adulthood), whilst many important features that predicted the progression of female

players occurred in early development. Specifically, during adulthood, progressed male players had perceived a greater exposure to blocked practice during the pre-season and more serial varied practice during the main season. Psychosocially, progressed male players reported a greater ability to cope, but were less likely to seek informational support from social media. During adulthood, progressed players perceived training sessions as less psychologically challenging. In contrast during early development, female hockey players were less likely to have practiced mental skills, perceived to be exposed to less anxiety, and were exposed less to context specific practice. Moreover, players perceived anxiety specific and skill practice less challenging. Additionally, progressed female players perceived having practiced a greater volume of serial varied practice during adulthood, were more likely to have attended a private college at 16 years, and have a parent who was a hockey player. Psychosocially, female players were likely to be less empathetic, but more likely to report perceived individual consideration from coaches. The discussion first presents male models followed by the female models in three developmental areas: practice and training, psychosocial characteristics, and multidimensional attributes.

Practice Attributes that Predicted Progressed Players

Progressed male players reported less variability in blocked practice in comparison to non-progressed players prior to the EDP. Less variability in blocked practice was a surprise given long term retention of skills is improved by contextual interference (Shea & Morgan, 1979). Contextual interference can be increased by manipulating the consistency and variability of a practice schedule (Buzzard, 2017). However, it is important to note that many contextual interferences studies have occurred within laboratories and highly controlled environments (Buzzard et al., 2020). Perhaps then, progressed male players were optimally challenged (Guadagnoll & Lee, 2004) considering at that specific point within the year. Whilst manipulating contextual interference may be important to provide challenge, male players may have been optimally challenged given the time in the year. This model may suggest that coaches could re-evaluate whether players need exposure to practice which has a high degree of contextual early within a main season to reduce the likelihood of over-challenging players, perhaps both technically and/or tactically.

In contrast, female players experienced less coach-led anxiety and context practice during early development. When female players were exposed to such practice, players perceived it as relatively less challenging to non-progressed players. This is perhaps a surprise

since anxiety and context specific practice can contribute to the development of expertise (Lawrence et al., 2014; Baker, Côté & Abernethy, 2003; Jeffreys, 2011). However, perhaps this finding may highlight that female players may not necessarily benefit from early exposure to pressure at a young age (i.e., <14 years). Particularly, when taken into context that female players were more likely to have a parent as a hockey player, perhaps players were already exposed to a pressured environment through home-life interaction. Perhaps then during adolescence, players may have already been over exposed to pressure through a cumulation of parental pressure and pressure created within a hockey environment. Without examining the family life dynamics amongst progressed and non-progressed players however, it is difficult to know the contribution of parental pressure. However, research does suggest that parental pressure can contribute to the development of maladaptive perfectionism (Flemming et al., 2022).

A comparison of male and female models revealed male hockey players may benefit from high constant block practice early in a main season (in adulthood), whereas female players may benefit from less exposure to anxiety specific practice during early development (i.e., pre-specialisation). Both these findings are against the talent literature which advocates for variability in skill development (e.g., Rothwell et al., 2017; 2020) and pressure within the practice environment (e.g., Law et al., 2022). Therefore, these findings may explain differences between players within this specific cohort. For example, with most progressed female players having at least one parent who was a hockey player, players may have already been exposed to a more optimal level of pressure. Taken together, these models may suggest that early in male development, coaches could be mindful of ensuring enough focus is placed on blocked-constant practice, whilst coaches for female players, could be re-evaluate whether pressure training is appropriate and necessary within early in adolescence.

Psychosocial Attributes that Predicted Progressed Players

Progressed male players reported a greater ability to cope with setbacks, likely through strong self-control and management mechanisms. Poor self-control and coping behaviours can be a risk factor in development of mental health illnesses (Souter, Lewis, & Serrant, 2018). Whilst social support was not highlighted within the pattern, visual inspection of the data suggested progressed players reported a stronger support network (i.e., autonomy, esteem, emotional, tangible, and informational) between main season 2019/20 and 2020/21 pre-season. According to (Freeman, Coffee, & Rees, 2011), higher levels of support (emotional, social,

esteem and tangible) were related with higher confidence and lower risk of burnout. This may suggest progressed players likely had overall lower risk of mental illness.

In contrast, the model that predicted progressed female players suggests players were less empathetic, more likely to perceive individual consideration from coaches, and more likely to aspire to a dual career. Whilst higher levels of empathy have not always discriminated between skill level (Budnik, Maria, Karol, & Maurizio, 2021; Shima, 2021), similar psychosocial characteristics such as selfishness, perfectionistic strivings along with a combined mastery and outcome focus have been shown to discriminate between elite and super-elite athletes (Hardy et al., 2017). Although the findings from Hardy et al (2017) cannot generalise to the findings of these studies, having low empathy alludes a focus on oneself. Paradoxically, it could be argued that despite being a team sport, having an element of low empathy may be beneficial in an elite female hockey environment. Moreover, taking into consideration other psychosocial characteristics, perhaps low empathy is a by-product of having perceived more individual consideration from coaches and extraversion. For example, perhaps progressed female players are excited to improve themselves by working on their weaknesses that players do not have any spare capacity to consider anyone else. This may perhaps be evidenced in an awareness to have a non-hockey career available after retiring from hockey through a stronger desire towards aspiring towards a dual career. Taken together, during an EDP pathway, progressed male players had developed psychological skills and coping mechanisms that enabled them to cope with setbacks, likely resulting in a reduce risk of mental health illness. In contrast, female players had developed psychosocial characteristics (e.g., extraversion) that may potentially enable them to use coach support, through having experienced greater perceptions of individual consideration.

A Multidimensional Model that Predicted Progressed Players

Progressed male players reported less instrumental support via social media during the 2019/20 main season in comparison to non-progressed players. A lack of instrumental support via social media may be explained by progressed players receiving support from other support networks sources. In line with early development, block practice was relatively important at adulthood. The finding that there was a greater perceived volume of blocked practice during the pre-season, and a greater perceived proportion of serial practice within the main season could be indicative of coaching planning (i.e., typically there is more time over the off and beginning of pre-season). However, it may be worth noting that progressed male players perceived having experienced a greater volume of serial-varied practice. Specifically, having

a greater degree of contextual interference may have contributed to the creation of a more optimally challenging environment (e.g., Guadagnoli & Lee, 2004). Indeed, considering male players were better able to cope with setbacks and use self-control mechanisms may have perhaps helped these players being able to cope with a relatively more challenging environment.

In contrast, female players were at greater risk of mental health illness, in comparison to non-progressed players. Whilst female players also reported having experienced less comprehensibility, they perceived the training environment as less psychologically challenging in comparison to non-progressed female players. This may suggest that despite having life stressors, adequate social support may have buffered negative consequences of stress and potential burnout (Lu et al., 2016), as having social support could potentially reducing the risk of mental health illness in elite athletes (e.g., Küttel et al., 2021; Sullivan et al., 2020). Whilst it is perhaps surprising that a form of social support did not emerge from the pattern, one reason why social support did not necessarily emerge could be because non-progressed players may have perceived similar levels (i.e., in the context of a global pandemic when many people had less access to social support networks, especially tangible). However, without analysing the perceptions of social support, it is unclear whether social support was a mechanism to explain the pattern.

Conclusion

Overall, relatively important features that predicted progression of male players occurred during early adulthood, whilst important features that predicted the progression of female players occurred in both adulthood and their early development (i.e., pre-specialisation). At adulthood, progressed male players perceived to have completed more blocked practice during the main season and were better able to cope with setbacks that may have been due to types of social support, other than instrumental support gained via social media. In contrast, prior to specialisation, female players perceived to have been exposed to less anxiety practice, had a parent that was a hockey player, and was more likely to have attended a private college. During early adulthood, female players were at great risk of mental illness but perceived their training environment as less psychologically challenging, possibly mediated through exposure to adequate social support. Talent together, the multidimensional retrospective-longitudinal model could suggest coaches may need to ensure both male and female players have adequate social support for their needs, whilst ensuring there is sufficient

opportunity for fundamental skill practice during early adulthood in male players, and carefully re-evaluate whether exposure to anxiety practice is necessary within early female development.

Appendix one

Table 1

Baseline characteristics of male and female players

	Male players		Female players	
Group characteristics	**Progressed**	**Progressed**	**Non-progressed**	**Non-progressed**
Mean age (years)	21.9	21.1	20.8	20.8
Mean age of specialisation (years)	14.8	14.1	14.7	13.6
Age of senior national league debut	17.0	16.7	16.1	15.9
Total hockey practice (hours) between 6–18 years	1400.0	1686.0	2121.0	1749.0
Total hockey competition (hours) between 6–18 years	565.6	196.5	304.2	659.7
Total practice in other sports (6-18 years)	2315.0	1562.0	1762.0	1343.0
Total competition in other sports (6-18 years)	844.9	467.5	575.7	557.6

General Discussion

National Governing bodies annually invest millions into their talent detection, identification, and development programmes to produce athletes who can win medals at major competitions (Feddersen & Halsted, 2021). Despite heavy investment, it could be argued that talent programmes do not provide an effective talent development environment due to the existence of talent wastage in many pathways (Bountakkis et al., 2018; Johnston & Baker, 2020). One reason that talent wastage exists in pathways is because talent development research is arguably overrepresented by monodisciplinary, cross-sectional, and retrospective designs that use traditional linear analyses particularly in male-only samples (Barraclough et al., 2022; Burgess & Naughton, 2010; Rees et al., 2016). However, such limitations highlight an opportunity for longitudinal and multidisciplinary research to advance our understanding of effective talent development in sport.

Chapter 1 attempts to overcome the limitations associated with retrospective designs by systematically reviewing multidimensional and prospective studies which have investigated talent development holistically. The findings provide future evidence to suggest physiological, physical, and technical skills develop non-linearly in adolescence. Moreover, the review highlights a lack of female and qualitative research meaning it is unclear whether male and female athletes have similar developmental experiences prior to an elite pathway. Chapter 2 suggests that, whilst there are psychosocial similarities, male and female players may prefer different types of social support during development. Chapter 3 builds on Chapter 2 by tracking the progression of elite male and female hockey players. The pattern recognition models suggest important features which predicted the progression of male players occurred during early adulthood, whilst important features that predicted the progression of female players occurred in both adulthood and their early development (i.e., pre-specialisation). Collectively, the studies from Chapter 1, 2, and 3 address the thesis aim by providing evidence for talent pathways to take into consideration male and female differences, investigate talent development holistically, and use mixed methods with prospective designs. These main findings of the thesis are presented and contextualised within the talent development literature to inform effective talent development in sport. In doing so, the main findings are firstly contextualised within the psychosocial literature and secondly contextualised within the development of expertise literature. These main findings are then presented together and contextualised within applied implications and future directions. Accordingly, this thesis

advances the talent development literature and makes progress towards reducing the likelihood of talent wastage in talent pathways.

Psychosocial Characteristics

Personality

Personality is an important and dynamic psychosocial construct that is needed for successful long term talent development (Allen et al., 2011). Five personality characteristics were proposed to explain patterns within human behaviour. Specifically, extraversion, conscientiousness, openness to experience, agreeableness, and neuroticism (McCrae & Costa, 2008; Allen et al., 2014). In the context of sport, these five personality traits likewise known as the 'big 5' can predict successful performance (e.g., Khan et al., 2016; Byrne et al., 2015). However, researchers suggests that performance and development can be impacted by other personality characteristics, beyond that of the big five such as perfectionism (Waleriańczyk & Stolarski, 2021), narcissism, and alexithymia (Roberts & Woodman, 2017). Although it could be considered that there is moderate evidence to suggest higher performing elite athletes have specific personality traits, further evidence is needed to better understand which combination of personality and psychosocial characteristics are needed within an effective talent development environment (Kaiseler et al., 2012) particularly within female athletes (Krause et al., 2021). Chapter 2 provides new insight as it found male and female hockey players who attained an international level of hockey by adulthood had: developed a strong work ethic; a pure enjoyment for hockey; experienced overcoming major setback; and relied upon a close and supportive network to help navigate and overcome the challenges they faced. Having a strong work ethic and overcoming a major setback (e.g., injury) can be supported by the findings from Hardy et al (2017), who found these characteristics could distinguish between super-elite and elite athletes.

Having a pure enjoyment of hockey may provide a protective mechanism against mental illness. This could be suggested because harmonious passion (i.e., a willingness & violation towards sport) has been positively correlated with wellbeing (e.g., Verner-Filion & Vallerand, 2018) and negatively correlated with burnout (e.g., Lopes & Vallerand, 2020) in male and female athletes. Identifying potential protective factors for mental illness is important when considering a finding from Chapter 1 highlighted female athletes may be at a greater risk of burnout in elite talent pathways. In agreement, Chapter 3 found progressed female players had greater signs of mental illness. Specifically, progressed female players reported higher

clinical indicators (i.e., signs of mental illness) and less comprehensibility within life at adulthood, in comparison to non-progressed female players. Additionally, prior to specialisation the model from Chapter 3 identified progressed female players had less exposure to anxiety during practice, a parent who was a hockey player, and had attended a private college from 16 years. Perhaps this background of combining features adequately supported progressed female players. Specifically, enabling them to cope better with stressors associated with elite competition at adulthood as adequate social support can buffer the effects of stressors (Freeman, 2021). Social support therefore may potentially explain why, despite having a greater risk of mental illness, these female players thrived within the talent pathway and progressed to the GB Senior Squad.

Social Support

Social support is important for practitioners to consider during development because it can help athletes cope with training and competition within an elite talent development environment (Kristiansen & Roberts, 2010; Morgan & Giacobbi, 2006; Sanchez et al., 2012) by buffering the effect of stress and reducing likelihood of depressive symptoms in elite athletes (Sullivan et al., 2020). As a multi-dimensional construct, social support can be categorised into esteem, emotional, tangible, and informational support (Rees & Hardy 2004; Freeman 2011) which may be received from different sources, such as coaches (e.g., Sheridan et al., 2014), parents (e.g., Park & Kim, 2014), and/or teammates (e.g., DeFreese & Smith, 2013). Social support has been found to benefit athlete performance (e.g., Trotter et al., 2021) and well-being (e.g., Malinauskas & Malinauskiene, 2018) likely by buffering the negative effect of stress (Rees et al., 2007; Freeman, 2021) and consequently reducing the risk of burnout (DeFreese & Smith, 2014; Gabana et al., 2016; Amemiya & Sakairi, 2020) and mental illness (Hagiwara et al., 2017; DeFreese & Smith, 2014; Gabana et al., 2016), especially in female athletes who have strong athletic identity (Russell, 2021). Combining the findings from Chapter 1 and 2 may provide a new insight by suggesting that while female athletes may be at a greater risk of mental illness, social support and a pure enjoyment for hockey combined may provide these players with a protective mechanism against the negative effect of stress and mental illness. However, a better understanding of which types of social support is needed in male and female athletes and exactly when in development will help practitioners better structure an effective talent development environment.

Tangible support reported in female players. A closer examination of a finding from Chapter 2 suggests parents could be an important source of tangible support for female hockey players "*They* [parents] *were literally the best taxi-drivers, driving us here, there, and*

everywhere..." A source of tangible support is important within athlete development because research has shown it can reduce stress and negative emotion (Freeman et al., 2014) and be an important element within successful injury rehabilitation (Rehmer, 2021). In line with the literature, it is likely that female athletes need a source of tangible support during development as it enables them to be driven to training grounds and have the kit that they need to continue within a talent pathway (Jowett & Timson-Katchis 2005; Arvinen-Barrow & Pack 2013). However, it is likely that other key stakeholders are needed to provide different sources of social support (e.g., Sanderson & Cassilo, 2019). For example, during development such as coaches. Coaches can be a source of informational support in an elite tennis pathway (Wolfenden & Holt, 2005; Koh et al., 2019) which may suggest players may rely on different aspects of social support (e.g., parents & coaches) which are potentially working independently in male and female athletes.

Informational support in male players. In contrast to female players who reported receiving tangible support, Chapter 2 found male players received informational support from their parents "*it's nice to get that perspective on things sometimes and just ask her honest opinion on things.*" For male players, having "*…that outsider's perspective has probably helped…especially growing up – 16, 17, 18 that was probably key then…"* which may suggest different aspects of social support are more important at different ages in development. A closer inspection of this extract may also suggest parents could be a source of conjunctive aspects of social support (i.e., esteem & informational support) for some male hockey players because his positively phrased extract may allude that his parents provided him with both advice as well as demonstrating listening and concern (Freeman, 2021). Taken together, these findings from Chapter 2 suggest aspects of social support may interact conjunctively within male development and perhaps more independently in female hockey player development, prior to an elite talent pathway in adulthood. In doing so, these findings build on the future directions advocated by Freeman (2021) and may suggest the importance of male and female players having access to an adequate social support network during development (Knight et al., 2018). However, these findings do not suggest the relative importance of different aspects of social support during adulthood (i.e., an elite talent pathway) and does not consider a potential role of technology in providing social support. Chapter 3 was the first study in hockey to investigate whether different types of social support are important in both male and female players within an elite hockey pathway.

Social support from social media. A finding from Chapter 3 highlighted that instrumental support via social media was greater in non-progressed male players in

comparison to progressed male players. This may suggest that social support via social media may not necessarily be an adequate form of social support for athletes in an elite hockey pathway. This finding is in line with research that has explored potential positive and negative effects that social media can have on athletes, especially during competition (Hayes et al., 2020). Whilst positive benefits of social media could include maintaining relationships with fans and stakeholders (Geurin, 2016; Hambrick & Kang, 2015), it is likely that the players within the EDP did not yet have a large enough fan base for social media to be an effective source of social support. Indeed, research has shown young male and female athletes (16–21 years) who overuse social media may increase their risk of sleep disorders, depression (Hudimova et al., 2021) and reduced self-esteem (Isaranon, 2019). Therefore, the findings from both Chapter 2 and 3 may provide new evidence to suggest the timing of the type of social support needed is an important feature for practitioners to consider throughout elite hockey players' development. For example, female players may need more tangible support whilst male players may need informational support during development prior to an elite hockey pathway. For an effective talent development environment, sport pathways may therefore need to consider that each individual player may need different combinations of social support depending upon current and prior social support and psychosocial experiences (e.g., type of athlete sources of social support that are available i.e., parents & coaches). These findings could suggest that, providing players perceive adequate social support for their individual needs, elite male and female hockey players may be more likely to progress through an elite hockey pathway, in comparison to male and female players who are not adequately socially supported.

Development of Expertise

Anxiety and Context Specific Practice

Female players. Coaches can reduce anxiety experienced by athletes by providing social support (Fogaca, 2021). Conversely coaches could promote feelings of anxiety by adjusting the practice environment because research has shown that learning a skill under pressurised conditions can subsequently lead to improved performance when these skills are performed under pressured conditions (Lawrence et al., 2014; Oudejans & Pijpers, 2010). However, studies supporting the role of anxiety in skill acquisition has been conducted within highly controlled laboratory conditions (Buzzard et al., 2021). Therefore, it could be argued that empirical support for creating anxiety in players within a training environment is limited by low ecological validity. However, whilst research has examined practice activities that may

have led to successful performance at adulthood (e.g., Güllich et al., 2019; Jones et al., 2019; Andrew et al., 2022), these studies have used retrospective deigns in male-only samples which limits our understanding of how practice activities in adolescence (i.e., pre-specialisation) interacts with practice activities (i.e., post specialisation) within an elite talent pathway (Andrew et al., 2022), especially within female athletes (Larkin et al., 2022). Therefore, it is not yet clear at which ages manipulating anxiety practice is most appropriate for long term athlete development, especially within female players. A finding from Chapter 3 suggests that progressed female players reported having experienced less exposure to anxiety practice prior to specialisation in comparison to non-progressed players. Whilst caution needs to be taken when generalising this finding, it may provide some evidence to suggest coaches may need to re-evaluate whether pressure training is necessary in female players' development prior to specialisation.

Structure of Practice

Male players. In contrast to female players, a finding from Chapter 3 suggested practice activities that were important within the progression of male players occurred post-specialisation. Specifically, progressed male players perceived themselves as having completed more blocked practice and being better able to cope with setbacks. When interpretating the findings across models (i.e., practice history & psychosocial characteristics), male players reported a greater volume of blocked practice across their development (i.e., pre & post specialisation). This finding is potentially surprising given the role of contextual interference in skill development (Shea & Morgan, 1979; Farrow & Buszrad, 2017; Buszard et al., 2017); contextual interference can increase the challenge when practicing skills (Guadagnoll & Lee, 2004). A practice schedule with a high degree of contextual interference, through random practice schedules, can benefit long term skill retention (Rendell et al., 2010). However, this finding may be explained in adulthood through the arrival of the COVID-19 global pandemic. During data collection, male players had not long returned from a period of national lockdown. From speaking with numerous club coaches (of the male and female EDP players), the 2020/21 main and pre-season was disrupted with COVID-19 restrictions and therefore may have been structured more in line with a typical pre-season, rather than a main season. This was an attempt to avoid physical overload of players, ahead of competition. Indeed, perhaps players perceived emotional support through their coaches' actions of adjusting the practice environment in response to the setbacks caused by the COVID-19 pandemic which helped enable male players to cope with the setbacks potentially associated with the disrupted training schedule. This could be suggested because the psychosocial pattern

recognition model highlighted that the progressed players reported their coach paid attention to the execution of their skills. Whilst without further data, caution would needs to be taken with this conjecture, viewing the multidisciplinary pattern in conjunction with the psychosocial pattern may further allude social support as a potential important mechanism underpinning the progression of male hockey players.

Multidimensional Approach to Talent Development

Applied Implications

With a predominant research focus on male athletes in talent development studies (e.g., Curran et al., 2019), the present findings from Chapter 2 advances the literature by highlighting the important role of personality in the progression of female hockey players. In line with the literature, progressed female players appeared to have developed psychosocial characteristics, such as extraversion, that may benefit performance (Gama et al., 2022; Blanch & Llaveria, 2021; Egan & Stelmack, 2003). Additionally, female psychosocial characteristics are important for coaches to consider given the recent investigation into attachment styles. Attachment style is important for coaches to consider in the context of the coach-athlete relationship (e.g., Davis et al., 2021). For example, coaches can have a positive impact on athletes' motivation providing that these athletes have a secure attachment. Conversely, if athletes have an insecure attachment with coaches, this can have a negative impact on athletes' motivation (Dock & Kvarnström, 2020). For example, perhaps an insecure athlete may not necessarily cope as well within an elite talent pathway as they may perceive lower levels of social support (Davis & Jowett, 2014). An important implication for an elite talent pathway is coaches need to be aware of the individual psychosocial differences between and within male and female athletes as this could impact how athletes cope with the environment. For example, in Chapter 2, the pattern revealed progressed female players had a stronger tendency to have a dismissive (insecure) attachment style, lower empathy, and clinical indicators of mental illness. When considering high levels of empathy can build resilience in male and female athletes (Morice-Ramat et al., 2018), low empathy may predict lower levels of resilience. Taken together, these combined psychosocial characteristics from Chapter 2 may explain why Chapter 1 highlighted female athletes may be at a greater risk of burnout during an elite sporting pathway. However, perhaps adequate social support may explain that despite risk of mental illness, progressed female players coped and progressed within an elite hockey pathway. Specifically, perhaps adequate social support may have buffered the effect of mental illness in these progressed female athletes (Kuettel et al.,

2021; Crutcher et al., 2018). This could be suggested because the combined findings of Chapter 1, 2, and 3 may suggest that despite tendencies towards having an insecure attachment style, female players progressed within an elite hockey pathway. Future research is needed however to further investigate how psychosocial characteristics interact within the talent development environment.

According to Chapter 1, 2, and 3, social support may be an important mechanism that impacts effective talent development in sport. For example, progressed female players reported that their training environment was less psychologically challenging, they had a parent that was a hockey player, and were more likely to have attended a private college at age 16 years. In line with the literature, these findings suggest the important role of parents as a source of social support (e.g., Poucher et al., 2018; Sheridan et al., 2014). An applied implication from these findings suggests it is prudent for practitioners to ensure athletes have a close supportive network (e.g., hockey parent) throughout the pathway. Moreover, when considering female athletes perceived a greater volume of serial-varied practice in comparison to non-progressed players, perhaps social support enabled them to cope with the challenge associated with greater contextual interference in serial varied practice relative to serial constant practice. Perhaps then, social support can also help athletes cope with challenge embedded within an elite practice environment (Wolfenden & Holt, 2005). Identifying differences in social support preferences in male and female athletes at different ages in development can therefore help inform practitioners how to better support individual differences in the practice environment.

Taking the main findings from Chapter 1, 2, and 3 together could provide evidence to suggest the importance of investigating talent development holistically especially within female athletes. For example, in female players, structuring talent development environments showed psychosocial characteristics (personality & social support) interacted with the practice environment (anxiety, context specific practice, & perceived challenge). Similarly in male players, the type of practice (blocked practice) and having an ability to cope with setbacks predicted the progression of male players. Taken together, this may suggest male and female players may need to develop specific psychosocial characteristics (e.g., extraversion in female players and an ability to cope with setbacks in male players) to progress with an elite hockey pathway. For example, female players may be able to cope with increases in anxiety in practice, providing that they have adequate social support networks and personality traits (e.g., extraversion). Therefore, to structure an effective talent development environment, coaches should consider individual psychosocial differences (e.g., availability of social support &

personality) especially when planning to expose female players to anxiety in the practice environment.

Limitations and Future Directions

Firstly, it took three months for me to travel to all players located in different clubs across the UK (i.e., Scotland, Wales & England) to collect 40 retrospective practice and training interviews. Therefore, it was decided for practicality and viability reasons, the mixed retrospective prospective element of the data collection would occur bi-annually instead of every three months as originally planned by the research team. Moreover, due to time practicalities we decided as a research team that it was not practical to additionally measure physiological attributes that may have been important to explain the progression of players. Secondly, with the arrival of the COVID-19 global pandemic during the first prospective-retrospective time point, all subsequent captures of players' practice and training activities were likely impacted by COVID-restrictions and therefore may not be a typical capture of practice activities during a typical season. Thirdly, due to an 18-month delay in the initial project set up, then an additional 6 months working with GB hockey, the data collection did not commence until September 2019. Consequently, the time for data collection was shortened from 36 months to 21 months.

Additionally, a limitation of pattern recognition analysis should be noted. Specifically, the machine learning algorithms cannot handle missing data points (Kuncheva, 2014). Therefore, a total of 8 players (6 male, 2 female) had to be excluded from the multidimensional model due to missing data points. In addition to limitations with the pattern recognition analysis in Chapter 2, for practicality reasons this investigation did not take into consideration how athlete psychosocial experiences interact with the psychosocial experiences of coaches throughout athletes' development. This is pertinent when considering athletes and coaches interact within a talent development environment (Taylor & Collins, 2021). Understanding how athlete and coaches' psychosocial experiences (e.g., social support) and practice and training environment prospectively interact could further advance the talent development and selection literature beyond that of investigating the coach-athlete relationship in a cross-sectional manner and monodisciplinary (Simons & Bird, 2022). Therefore, to further inform effective talent development, future talent development research could be built on this thesis by prospectively investigating the multidimensional characteristics in male and female hockey players and how these interact with coaches throughout an elite sporting pathway.

General Conclusions

Chapter 1 further identified the need for prospective and multidimensional talent development research, particularly in female athletes. Specific psychosocial experiences and characteristics may be needed to attain a place within an elite hockey pathway, irrespective of sex. However, other multidimensional characteristics may be needed to develop to ensure the progression of male and female players. For example, it may be important for male players to have adequate exposure to blocked practice and be able to overcome setbacks during adulthood, whilst it may be important for female players to have less exposure to anxiety practice prior to specialisation. Post specialisation (at adulthood), female players may be at a greater risk of mental illness but may rely on adequate social support to mitigate this increased risk. Together, these findings may suggest coaches need to re-evaluate whether anxiety specific practice is necessary in young female players prior to specialisation, especially if they do not yet have the social support networks or psychological skills needed to cope with a high pressurised practice environment. Future research is needed to replicate these combined findings in another cohort of elite hockey players and prospectively investigate how individual psychosocial characteristics interreact with the practice environment and coaches (throughout player development). In doing so, the talent development literature and sport pathways will be another step closer towards reducing the likelihood of talent wastage in elite talent pathways.

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