A MULTIDIMENSIONAL APPROACH TO QUANTIFY SKILL AND MATCH PERFORMANCE IN YOUTH FIELD HOCKEY

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Abstract

This thesis sought to address two aims. The first aim was to evaluate what performance characteristics distinguish between skill levels at different stages of development (age) by using a multi-dimensional objective approach to performance testing in field hockey. In order to achieve this aim, representative state level players and club level players completed anthropometric, physical capacity, sport-specific technical skills, decision-making skills, self-regulatory skills and developmental sporting history assessments (Chapter 3). It was revealed that representative level players selected by experienced selectors and coaches were those players that possessed superior dribbling skills, passing/hitting skills and speed and endurance capacities. Although decision-making skill discriminated between male players, a significant difference in decision-making skills between female state and club level players was absent. The results of the self-regulation questionnaire did not reveal any differences between playing levels. However, for both the decision-making skill and self-regulatory skills, the differences between playing levels were not the same across all age groups, which might indicate that selectors weight the importance of different performance characteristics relative to age or stage of development. An important finding of this study was that maturational status and the developmental practice history of the athletes had a strong influence on the chance of selection into a representative team. It was suggested that policy makers should incorporate guidelines for selection that account for these factors, as they don't always translate into future sporting success.

The second aim of this thesis was to gain a better understanding about the influence of competition and training environments on the development of necessary field hockey skills. In order to achieve this aim, two different experiments were conducted. Firstly, the influence of manipulating the number of players and personal playing area on sport-specific technical skill, physical and decision-making demands in U12 competition environments was determined (Chapter 4). It was revealed that lowering the number of players from 11 per side to 8 per side increased the number of technical actions performed per player and also increased the temporal demands of the game. Scaling the personal playing area per player only affected the number of unsuccessful dribbles. The increase

in technical actions due to the lowering of player numbers provides young field hockey players with more opportunities to develop technical skills while the increased temporal demands are likely to promote the development of appropriate decision-making skills. It was argued that the findings of this experiment emphasised the dynamic nature of performance as players' behaviour was guided by the interaction of organismic, environmental and task constraints (Newell, 1986). It is suggested that policymakers consider such findings when developing appropriate competition environment for young field hockey players.

A second experiment determined the influence of eight different small-sided games (SSG) on physical, technical and decision-making demands of training performance of U14 field hockey players (Chapter 5). The eight SSG were a combination of manipulating the number of players (3 per side or 6 per side) and field characteristics (normal game, cage hockey game, possession game and two goals game) and it was revealed that consistent with the findings of chapter 4, lowering the number of players increased the number of technical actions performed per player and the physical demands of the SSG. Findings of the field characteristics manipulation revealed that the possession game forced players to control the ball more as a team which resulted in more passes and fewer dribbles and tackles. The two goals game provided players with more scoring opportunities while the cage hockey game increased passing and physical demands. It can be concluded from these findings that coaches are able to promote a change in playing behaviour, and in turn the development of skills, by manipulating specific constraints of the training environment.

Overall, this thesis highlighted the dynamic nature of talent selection as well as talent development. It is suggested that policy makers and coaches need to be aware of these interactions and account for this in their talent selection and talent development policies to create environments where learning is optimised. This in turn will maximise the chance of young athletes reaching a higher level of sports expertise.

Student Declaration

I, Ewout André Timmerman, declare that the PhD thesis entitled "A multi-dimensional approach to quantify skill and performance in youth field hockey" is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature: [redacted] Date: 16/11/2016

Acknowledgements

So this is it, I'm actually writing my acknowledgements. That means that I'm about to finish my PhD thesis. I never thought it would happen. What started out as a joke in the bar ends with the submission of this thesis, which has become so much more than just a thesis for me.

February 2012, eating sushi at the airport with Joel de Water, the start of my Master Internship at Victoria University, Melbourne, Australia with Prof. Damian Farrow. An investigation in the effect of manipulating net height and court dimensions in tennis leads eventually to the publication of my first paper. In the meantime, Hockey Australia aims to collaborate with Damian to gain more knowledge about talent identification and talent development in field hockey. Damian offers me the opportunity to be part of this beautiful 3-year project. An offer I can't refuse.

April 2013, eating sushi at the airport again, just by myself. I managed to finish my Master in Human Movement Sciences at the Vrije Universiteit in Amsterdam and I'm about to start a PhD at Victoria University, Melbourne in collaboration with Hockey Australia and Damian Farrow and Geert Savelsbergh as my supervisors. What can I say, I'm part of a dream team ☺.

Damian, you're the coach of the team and my biggest mentor. First of all, thank you very much for putting me forward to join the PhD project with Hockey Australia. It's great to find out that someone of your caliber has the idea that I was capable enough of finishing the PhD. Hopefully I didn't let you down over the years and was I able to meet your expectations. Secondly, thanks for letting me go back to the Netherlands to write a big part of my thesis. Thirdly, I would like to thank you for the way that you, and your family, welcomed me in Australia. You became so much more than just a supervisor for me; you acted as a guide into the Australian way of life. You introduced me to surfing, footy and the art of BBQ-ing and making pizzas. I'm afraid I only picked up on the BBQ skills!

Geert, you were on the advisory board of the team. The first few years I have barely seen you, but you were always there to provide expert advice on the proposal of the PhD and design of the experiments. Your experience in designing world leading research was great and helped the project moving forwards. In the last year, you stepped out of the advisory board to join the coaching team when I decided to write my thesis in Amsterdam. Thank you for the help and guidance during this process, I really enjoyed working with you more closely over the last months.

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I have been playing field hockey for many years now, so I know you need a team to perform well. And I have been very lucky with my office team. All the members of the office P-141 team have made a serious contribution to my PhD. Michael, Jacky, Jason, Shelley, Georgia, Ineke, Jade, James and Tim, thanks for putting up with me over the last 3.5 years. You have been amazing in creating an enjoyable working environment and probably more important for me, you have been great in creating a working environment where I could be myself and feel welcomed. Especially when times were tough, you were there to help me.

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Next to my Australian team, I was lucky to have an amazing Dutch team as well. Friends from university, friends from field hockey and friend from high school, every time I was back in the Netherlands you made my stay into a great one. I could always count on big night outs, day festivals and dinners when I was back in my home country, but also when the times were tough, you guys were there for me to support me. Dankje wel jongens, dat doet me goed.

Although I had a good advisory board, a great coach and amazing teammates, the PhD-ride has not been easy for me. I have learned a few things about myself that I didn't know before. I thought I was resistant to stress, but I very soon figured out I'm not. Recruiting participants, preparing data collection, data collection itself and submitting a manuscript at a Journal, it all led to headaches and sleepless nights. I learned to deal with setbacks, sudden change of plans and rejections and this helped me to grow up as an academic as well as a person.

After 3.5 years of work, I think I can be proud of the things that I have accomplished for this PhD-project and now it is time to celebrate. Although the celebrations will be good, in the company of many good friends in Australia and the Netherlands, I will be missing two very important people to celebrate with me. Dad, I haven't seen you for over 10 years now and I sincerely hope I make you proud with everything I do. Mum, you supported me to go to Australia, not knowing that the goodbye at Schiphol would be the last time I saw you in healthy conditions. Although the last 3 months of your life were extremely hard for all of us, I'm thankful that I could be part of it. Mum and dad, I feel privileged to be your son and still miss you every day.

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In loving memory of Mum and Dad

Take that rage, put it on a page
Take that page to the stage
Blow the roof off the place
I’m trying to make you proud
Do everything you did
I hope you’re up there with God saying “That’s my kid”

I still look for your face in the crowd
Oh if you could see me now (2x)
Would you stand in disgrace or take a bow
Oh if you could see me now (2x)

If you could see me now would you recognise me?
Would you pat me on the back or would you criticize me?
Would you follow every line on my tear-stained face
Put your hand on my heart that was cold
As the day you were taken away

If You Could See Me Now – The Script

List of publications & presentations

Sections of this thesis have been published (or submitted for publication) and/or presented at relevant scientific conferences.

Publications in refereed Journals

Chapter 4

Timmerman, E.A., Farrow, D., & Savelsbergh, G.J.P. (under review). The effect of manipulating task constraints on game performance in youth field hockey. *International Journal of Sport Science & Coaching*.

Other publications during my PhD

Timmerman, E.A., de Water, J., Kachel, K., Reid, M., Farrow, D., & Savelsbergh, G.J.P. (2014). The effect of equipment scaling on children's sport performance: The case for tennis. *Journal of Sports Sciences, 33,* 1093-1100.

Conference Presentations

Timmerman, E.A., Savelsbergh, G.J.P., & Farrow, D. (June 2015). *The effect of manipulating task constraints on skill performance in field hockey*. Australasian Skill Acquisition Research Group (ASARG), Perth, Australia.

Timmerman, E.A., Savelsbergh, G.J.P., & Farrow, D. (April 2016). *The development of a holistic testing battery for talent identification in field hockey*. Science and Engineering Conference on Sports Innovations (SECSI), Amsterdam, The Netherlands.

Timmerman, E.A., Savelsbergh, G.J.P., & Farrow, D. (July 2016). *The effect of manipulating task constraints and player number in small-sided games in field hockey*. 6th Teaching Game for Understanding (TGfU) Conference, Cologne, Germany.

Conference Posters

Timmerman, E.A., Savelsbergh, G.J.P., & Farrow, D. (June 2016). *The development of a holistic testing battery for talent identification in field hockey*. North American Society for the Psychology of Sport and Physical Activity (NASPSPA) Conference, Montreal, Canada.

Invited Seminar Presentations

Timmerman, E.A. (May 2016). *The development of a holistic testing battery and it's implication for talent identification*. Invited presentation at the MOVE research Institute at the Faculty of Behavioural and Movement Sciences, Amsterdam, The Netherlands.

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Chapter One

Introduction and overview of the thesis

1.1 Introduction

Every year, many sports invite young athletes to attend 'talent'-days or try-outs. These young athletes dream of being picked for a squad to be able to further develop their talent to play at the highest level and become the next Messi, Michael Jordan, Serena Williams, Jamie Dwyer or Luciana Aymar. The search for and quantification of talented youngsters is achieved via many different methods depending on the sporting organisation. For example, a draft pick system is used in sports such as basketball (NBA) and Australian football (AFL) where talented 16-18 year old players can be drafted into a professional team at a specific point in time. During the draft period, young and talented players have to perform a set of sport-specific performance tests with the data used by the professional teams to pick the players that they think fits their team's needs best. In contrast, young talented soccer players are scouted on the playing field by selectors of a club or national team. Each selector will use his own (subjective) experience and knowledge to select a young player to play and join the talent development program of that organisation. Although selectors are looking for performance characteristics that are specific to their sport, they are all looking for the talented player who performs better than the rest of his team or opponents. More so, selectors and scouts are looking for that player who they think is able to become the next expert performer based on current performance.

Inspired by his cousin Charles Darwin and his seminal text "The origin of species", Francis Galton became strongly devoted to exploring variation and exceptional performance in human abilities. Galton was interested in determining if human abilities were hereditary, and examined if there were more "eminent" men among relatives compared to the general population. Galton found that the abilities of "eminent" men were hereditary but he also recognised several flaws in his work and proposed to explore human abilities by comparing twins (Galton, 1876). From the twin-studies, Galton concluded that human abilities were mainly driven by nature and his work sparked the somewhat ongoing debate about nature vs nurture. The idea that behaviour is hereditary led eventually to the start of the Human Genome project and with its completion in 2003; it was strongly believed that human behaviour originated in our genes. In contrast to the belief that behaviour is genedependent, environmentalist's believed that every person started as a blank state and that all human behaviour and in turn expert performance is the result of experience and learning during life. In more recent years, the relative contribution of genetic factors to aerobic fitness in 16-18 year old twins revealed that from childhood to adulthood, genetic factors determine more than half of the individual differences in aerobic fitness (Schutte, Nederend, Hudziak, Bartels, & de Geus, 2016). This finding emphasises the belief that human abilities are not solely influenced by genetics or the environment, but are a result of the interaction between genetics and the environment.

The search and quantification of exceptional human abilities could also be considered the stimulus to consider the identification and development of sports expertise. Firstly, fuelled by the nature vs nurture debate, researchers believed that innate abilities such as visual and cognitive processing skills differed between novice and expert athletes and could explain differences in sport-specific performance. However, Starkes (1987) differentiated perceptual 'hardware' (e.g., vision and reaction time) from "software" (sport-specific perceptual skills) of elite, sub-elite and non-elite field hockey players and findings revealed that elite field hockey players outperformed their non-elite peers on sport-specific perceptual skills whilst their performance on 'hardware' tests did not differ. These findings have continued to be demonstrated in various sports and populations such as soccer players (Helsen & Starkes, 1999), clay target shooters (Abernethy & Neal, 1999) and American football players (Garland & Barry, 1991). Consequently, over the last few decades, the ability or amount of skill an athlete possesses is typically measured by evaluating sport-specific perceptual, physical and technical skill capacities of a young athlete. However, more recently, generic motor coordination tests have also been used to discriminate between talented and non-talented athletes (Faber, Oosterveld, & Nijhuis-van der Sanden, 2014; Vandorpe et al., 2012) and to discriminate between athletes of different sports (Pion et al., 2015).

This quantification of sports expertise has led to the identification of numerous potential contributors to sports expertise (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Hoare, 2000; Jonker, Elferink-Gemser, & Visscher, 2010; Reilly et al., 2000; Ward & Williams, 2003). It has been demonstrated that expert athletes possess superior physical abilities, sport-specific technical skills, decision-making skills and psychological traits over sub-elite athletes and that when combined several of these performance characteristics are able to predict someone's potential to become an expert performer with a reasonable degree of accuracy (Falk, Lidor, Lander, & Lang, 2004; Till et al., 2015). The discriminative performance characteristics are deemed to be important skills for players to possess to be able to compete at a high level of competition and it is suggested that coaches and trainers should create learning environments where players can develop these necessary skills. Therefore, in this thesis, it is suggested that the development of sports expertise in field hockey should focus on performance characteristics known to discriminate the better players from the rest. Although the identification of talented athletes based on a singular performance characteristic has shown to be successful in some instances (Gil, Ruiz, Irazusta, Gil, & Irazusta, 2007; Mikulic & Ruźic, 2008), it is emphasised that sports expertise, particularly in team sports such as hockey, is multi-faceted and that talent selection protocols should account for this feature (Faber, Elferink-Gemser, Faber, Oosterveld, & Nijhuis-van der Sanden, 2015; Woods, Raynor, Bruce, McDonald, & Robertson, 2016).

The development of sports expertise and in turn, the chance for selection into a representative team, is the result of a complex interaction between personal and environmental factors and an extensive amount of domain specific training (Baker & Horton, 2004; Ericsson, Krampe, & Tesch-Romer, 1993; Rees et al., 2016). With the use of retrospective training data sourced from expert performers, research suggests that young athletes have to invest in an extensive amount of practice and have proposed several developmental pathways to sports expertise: early specialisation (Ericsson et al., 1993), early diversification (Côté, 1999) and the early engagement hypothesis (Ford, Ward, Hodges, & Williams, 2009). In these models of sports expertise, the macrostructure of training is described; however, it is suggested that it lacks detailed information on the microstructure of training. This is despite guidelines for evidence-based skill acquisition strategies that can be used to improve sport-specific skills being readily available (Williams & Hodges, 2005).

A useful theoretical framework to understand the role of skill acquisition in the development of sports expertise is the constraints-led approach (Davids, 2010; Davids, Button, & Bennett, 2008) which is based on the work of Newell (1986). This model argues that there are three types of constraints influencing the acquisition of movement and coordination of actions: organismic, task and environmental constraints. The interaction between the three types of constraints dictates the available perceptual information that players can pick up to guide their behaviour and for skill acquisition, and means that players have to pick-up specific information from the environment and create information-movement couplings (Jacob & Michaels, 2002). It is suggested that the learning environment has to be representative of the performance context to create appropriate information-movement couplings (Pinder, Davids, Renshaw, & Araújo, 2011). A method widely used by coaches and trainers to create an appropriate learning environment is the modification of task constraints such as sporting equipment, field dimensions and the number of players. These manipulations have been shown to influence playing behaviour of athletes and in turn, it is suggested that these manipulations will influence the development of necessary sport-specific skills and in turn sports expertise (Gabbett, Jenkins, & Abernethy, 2009; Silva et al., 2014). It is therefore of great importance to examine the influence of manipulating task constraints on the playing behaviour of young athletes in field hockey as this will likely influence the development of necessary field hockey skills.

1.2 Thesis organisation

The thesis consists of six chapters. Chapter 1 introduces the topic of the thesis. Chapter 2 provides an overview of the existing literature on talent development models, characteristics influencing field hockey playing performance and the effectiveness of manipulating task constraints on the emergence of critical field hockey skills and provides the experimental aims. Chapter 3 focuses on the identification of performance characteristics that distinguish between skill levels at different stages of development. Using a multi-dimensional objective approach to performance testing in field hockey the anthropometric, physical capacity, sport-specific technical skills, decision-making skill, self-regulatory skills and the developmental sport history of selected (i.e., state) and non-selected (i.e., club) field hockey players were assessed to gain a better understanding of the qualities that underpin selection into a representative state team in field hockey. A key part of this experiment was to determine the influence of factors such as maturational status and training history on the selection into a representative state team. Chapter 4 determines the effect of manipulating competition structures on the technical, decision-making and physical demands of youth field hockey. Specifically, the individual and interactive influence of two key task constraints: the number of players in a game and the personal playing area per player (density) were examined. Chapter 5 presents an experiment where the effect of manipulating SSG on playing behaviour was examined. The individual and interactive influence of two key task constraints: the number of players in a game and the field characteristics of SSG were manipulated. This resulted in eight different SSG being played where the technical, decision-making and physical demands were determined as in Chapter 4. Chapter 6, the final chapter, summarises the findings of each chapter and discusses the theoretical and practical implications of the research, as well as providing directions for future research.

Please note that Chapters 3, 4 and 5 have been written as “stand-alone” chapters with the intention to publish and, subsequently, the definitions of key terms (e.g. constraints-led approach, self-regulation, maturational status) and some of the key introduction and discussion points are unavoidably repeated in several chapters.

Chapter Two

Literature review

2.1 Introduction

Nowadays, people are able to watch professional sports 24 hours a day from all over the world. This development has led to an increase in revenue in professional sports as well as a more professional attitude towards the identification and development of talented athletes by clubs and sporting organisations to identify the next superstar. Over the last few decades, this search and quantification of sports expertise has also been a major focus of sport science. Findings have revealed that expert athletes outperform their non-expert peers on technical skill abilities, physical abilities, perceptual-cognitive skills and psychological traits (Faber, Bustin, Oosterveld, Elferink-Gemser, & Nijhuis-van der Sanden, 2015; Rees et al., 2016; Reilly, Williams, Nevil, & Franks, 2000). Furthermore, it is argued that the development of sports expertise can be facilitated in many different ways with some arguing that young athletes should invest in only one sport (Ericsson, Krampe, & Tesch-Römer, 1993) while others argue the benefits of sampling multiple sports (Côté, 1999).

This chapter will focus on the dynamic process of talent identification and talent development in the journey toward sports expertise with a special focus on field hockey. Therefore, key terms such as talent identification, talent detection, talent development and talent selection in relation to team-sports will be discussed. Secondly, several talent development models in the domain of sports will be critically discussed. The described talent development models were based on their significant influence on the talent development literature as well as their influence in the practical setting. Thirdly, potential contributors to the development of expertise in field hockey will be reviewed in order to highlight the need for a multi-dimensional and objective approach to talent identification. The described performance characteristics were chosen based on the intrapersonal and environmental factors detailed within Gagné's (2004) model of talent development as this model is one of the few models that provides detailed information on types of influential factors on talent development. Fourthly, the influence of the relative age effect and maturational status on the identification of talented athletes as well as the influence on talent development will be provided. Finally, this chapter aims to discuss the constraints-led approach as a theoretical framework for the development of necessary field hockey skills.

2.2 Definitions of talent, talent identification and talent development

Many children dream to excel in sports as basketball, field hockey, soccer and American football and spectators are willing to pay significant money to watch high quality competition. To make sure that spectators keep coming to their matches, professional sporting clubs and sporting organisations are investing significant amounts of money into the selection and development of potential expert performers. Talent scouts wander around the pitches to unearth players who possess certain characteristics that they think are important to become an expert performer. However, this approach is suggestive and subjective. From a scientific perspective, Howe, Davidson and Sloboda (1998) argued that five properties can be assigned to a talent: (1) characteristics are partly innate, (2) the full effects are not evident at a young age but some indicators of exceptional performance are presented, (3) these early indicators are the basis for talent prediction, (4) not everybody is talented and (5) talents are domain specific.

The process of scouting and developing players to become expert performers consist of four different stages: talent detection, talent identification, talent development and talent selection (Williams & Reilly, 2000) (see Figure 2.1). Talent detection is the discovery of future players who are currently not enrolled in a sport. This stage is particularly difficult for minority sports where there are less people interested in playing their sport. The second step is talent identification and during this process players are recognized who have the potential to become an expert athlete. According to Bar-Or (1975), talent identification is a five step process:

1. Children are evaluated on anthropometric, physical, psychological and performance variables.
2. Their results are weighted against their biological age.
3. Their reaction to training is tested.
4. Their family history is evaluated.
5. A multiple regression analysis is used to predict the performance of a child.

One of the main questions during the talent identification process is whether an athlete could benefit from a systematic training program. When selected as a potential expert performer, players will be drafted into a talent development program. In such a program, it is aimed to create an appropriate learning environment where all the necessary support is provided. An important part of being involved in a talent development program is the investment in an extensive amount of qualitative and intense training hours that aim to improve the skills of the athlete. Due to the highly dynamic nature of development and performance, talent selection is an ongoing process where players are selected to play for a team or squad at a certain time. For example, in a sport such as field hockey, only 11 players are allowed to play at one time and therefore coaches will pick the players who are best able to fulfil the task within a game.

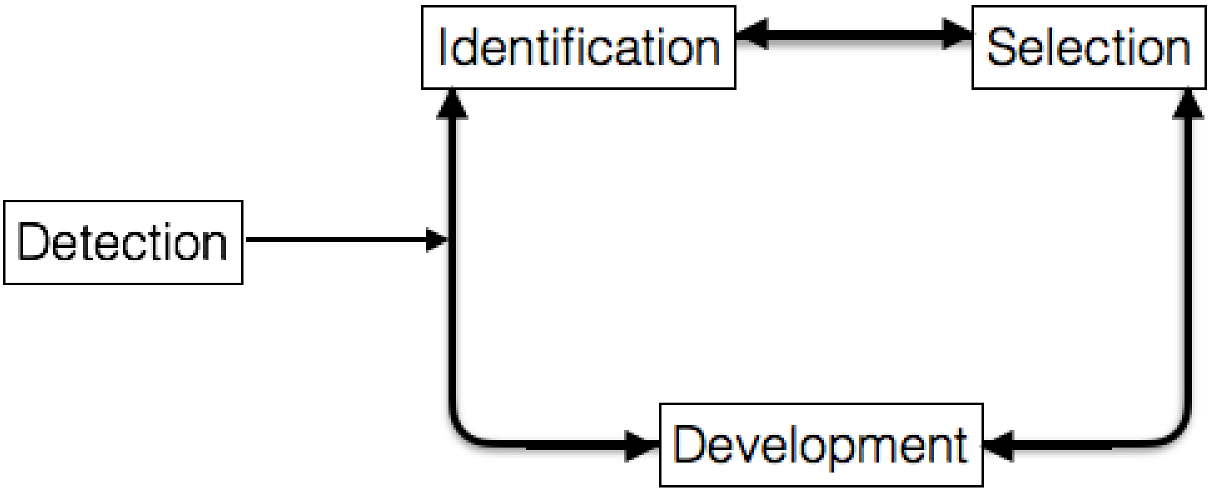

Figure 2.1. Key stages of talent identification and talent development process (reproduced from Williams and Reilly, 2000).

Talent identification and talent development is a dynamic process that differs over time. Talent identification is based on a set of performance characteristics recorded at a young age that will arguably result in the identification of a group of the current 'best' players with the most potential (Cobley, Schorer, & Baker, 2012). Once selected, the performance of this group and other athletes will be evaluated for selection into the next developmental stage. At this stage, the selection criteria can change as different performance characteristics are deemed to be more important for expert performance. This process is likely to occur multiple times and at each selection moment, the pool of talent decreases and a more homogeneous group of athletes is formed. Players who are not selected for the next representative squad are advised to keep competing at the current level or drop to another performance level. In theory, the result of all the selection moments, each focusing on different performance characteristics, is a well-rounded athlete with all the necessary skills to perform at the highest (international) level.

For each sport, different selection criteria will be adopted and for each stage of talent identification and talent development different performance characteristics will be regarded as more important. However, two general assumptions apply to the process of talent identification and talent development which also highlights the challenges of this process (Cobley et al., 2012). The first assumption is that talent is identifiable and measurable. This implies that there are certain performance variables related to the amount of talent an athlete possesses and that we can use tests to quantify this. The second assumption is that adult performance can be predicted by youth performance. This implies that the results of performance testing at a young age successfully predict who will become an expert athlete at the adult age. For sports as rowing, running and cycling (so called 'closed' tasks or CGS-sports) there are specific physical and anthropometric performance tests that can have a high predictive value, however, in invasion games such as soccer and field hockey these tests seem to lack predictive power.

2.3 Talent development models

The identification of talented players in team sports has become a significant focus for sport's governing bodies as well as for researchers. Talented players are selected to play for representative state teams in Australia as young as 12 years of age, in the case of cricket, field hockey and soccer and from 13 years old in the case of basketball. Sport's governing bodies hope to be able to select players that have the potential to become expert athletes at a senior age and compete at the highest (inter)national level. However, a study into the developmental pathway of senior champions in game-sports suggests that only 7.2% of the athletes had a linear development trajectory while 70.3% of the athletes had a mixed descent trajectory which means that these athletes moved to lower competition levels during their development (Gublin, Weissensteiner, Oldenziel, & Gagné, 2013). Furthermore, retrospective data of German field hockey players revealed that players of the 2012 Olympic Champion team were recruited significantly later for a federation squad compared to national class players, at 16.2 years old and 14.9 years old respectively (Güllich, 2014). Although the selection into a representative team means a player has access to better facilities, better coaches and more training, the predictive value and efficiency of these selections at the younger ages is reasonably low (Gublin et al., 2013; Güllich, 2014). Before being selected as a talented athlete, players go through different pathways of development to reach an expert level in their field. This developmental process or pathway of talented people has received great interest for many years and is detailed below.

2.3.1 Bloom's three stage model

Benjamin Bloom (1985) was one of the first to describe the process and pathways of talent development in detail. In his book, the developmental pathway of expert academics, athletes and musicians were described with the use of retrospective data gathered through semi-structured interviews. From the retrospective data of the different experts, it was clear that three distinctive learning phases were present in their developmental pathway: early years, middle years and the later years (Bloom, 1985). Although data is presented from different domains, the point of focus here is on the developmental pathway of athletes. In the early years, the expert athletes became acquainted with their main sport in a playful way, in this period children became comfortable with their sport before recognising it as a real sport. The focus of 'training' was on having fun and being physically active which slowly evolved into a more competition based environment where athletes start to compete with peers. During these competition experiences, the young athletes experience success which drives them to be more serious about the sport and this is also where they transform into the new phase of learning: the middle years. For most athletes, this transfer occurs between the age of 9-11 years old and training becomes more structured and the focus is on improving competence instead of just having fun. The commitment to the main sport grows and sacrifices have to be made to put in the necessary hours of practice. According to most of the expert athletes this commitment and sacrifice were easily made as successes inspired them and motivated to keep going and it is also at this point, that the athletes became recognised as 'talented'. The definition of being talented is one where a child demonstrates an unusually high level of ability, achievement, or skill in some special field of study of interest (Bloom, 1985, p 5). As highlighted earlier, the definition of talent is problematic for sports scientists as it is difficult to determine whether skilled performance as child eventually translates to expert performance in adult competition. Over the years, players then commit to more hours of training with the focus on improving technical skills in an efficient way to be able to compete at the highest level of competition and live up to the potential of being talented. The next and last step highlights the last learning phase, where athletes become fully devoted to their sport: the later years. In this phase, athletes devote all their time to their sport and compete at the highest international level of competition.

Support for the developmental pathway proposed by Bloom is provided by 26 international figure skaters from the USA (Scanlan, Ravizza, & Stein, 1989). It was shown that 85% of the international figure skaters followed the three different stages proposed by Bloom for the development of sport expertise. Features such as increased specialisation, commitment, financial demands and competition were reported by the figure skaters and highlighted the stages proposed by Bloom. However, a limitation of the work of Bloom (1985) and Scanlan et al. (1989) is that all athletes were North American. The college system that is in place in the USA differs significantly from the Australian and European sporting systems, what is mainly club based. A second limitation of the subject pool described by Bloom and Scanlan et al. is that all athletes were individual athletes (tennis, swimming and figure skating) which could potentially limit the extent to which the model is able to describe the development of sports expertise in team-sports. Despite some of the limitations of Bloom's three stage model, the model highlights the importance of the transition between different stages and the influence of parents and coaches.

2.3.2 Deliberate practice theory

For many years, the superior qualities of expert performers have been attributed to their innate abilities. However, Bloom's (1985) work highlighted that talented athletes have to commit to an extensive amount of practice to reach an expert level and innate abilities are possibly only part of the story. Indeed, it was argued that master chess players developed their superior specific chess abilities through years of practice and an accumulation of thousands of hours (Simon & Chase, 1973). From this study and more studies into the differences between expert and non-experts it was argued that the type of practice was of significance (Ericsson et al., 1993). Labelled deliberate practice, Ericsson et al. (1993) defined it as highly structured, requiring effort, not inherently enjoyable with the aim being to improve performance (p. 368). The role of deliberate practice was examined with the use of retrospective data to determine the number of accumulated hours per week of deliberate practice and whether it separated the elite, sub-elite and non-elite students and professional violinists. Findings revealed that with age, the amount of practice hours per week increased for all groups. When accumulating the hours per week into the amount of hours per year, it was clear that by the age of 18, the amount of deliberate practice was significantly different between the performance levels. The elite young violinists had accumulated a total of 7,410 hours of practice compared to the 5,301 hours of practice accumulated by sub-elite young violinists. No significant difference was found between the elite young violinists and the professional violinists (Ericsson et al., 2013). Similar results were found when the practice history of expert pianists and amateur pianists were compared. Findings revealed that at the age of 18 years old, expert pianists had accumulated 7,606 hours of deliberate practice while amateur pianists only accumulated 1,606 hours of deliberate practice. The overall finding of the work of Ericsson (2004, 2008; Ericsson et al., 1993; Ericsson & Charness, 1994) showed that there was a strong correlation between the performance level and the accumulation of deliberate practice over the years. Additionally, it was demonstrated that experts started to engage in their domain at a younger age and these differences between experts and non-experts seems to be evident in different domains. From this work it can be concluded that expert performance can only be reached through the accumulation of an extensive amount of deliberate practice and early engagement in a specific domain. Approximately 10,000 hours and a decade of intense practice has been suggested to reach expert performance and three types of constraints interact during such deliberate practice: motivation, effort and resources (Ericsson et al., 1993; Helsen, Starkes, & Hodges, 1998). As deliberate practice is not inherently enjoyable, athletes have to be motivated to persist and put effort in to practice to improve performance. Next to these personal characteristics athletes have to have access to facilities and coaches to create the appropriate training environment to improve performance (Ericsson et al., 1993).

Soon after the work of Ericsson, et al (1993), the influence of the accumulation of extensive amounts of deliberate practice on the development of sport performance was explored (Hodges & Starkes, 1996). Retrospective data on practice history of international level and club level wrestlers revealed that international wrestlers had accumulated 5,882 hours of practice while club level wrestlers only had accumulated 3,571 hours of practice. Helsen et al. (1998) further explored the influence of deliberate practice on the development of performance in team sports. Significant differences in the amount of practice were apparent between international, national and provincial soccer players at the age of 18 and at the age of 23, international level players had accumulated 9,332 hours practice, national level players had accumulated 7,449 hours of practice and provincial players had accumulated 5,079 hours of practice. Similar findings were apparent between international, national and provincial field hockey players. At the age of 27, international, national and provincial players had accumulated 10,237 hours, 9,147 hours and 6,048 hours, respectively (Helsen et al., 1998). Consistent findings for the positive relationship between the amount of practice hours and performance level has been found in sports such as darts, gymnastics and soccer (Duffy, Baluch, & Ericsson, 2004; Law, Côté, & Ericsson, 2007; Ward, Hodges, Starkes, & Williams, 2007).

However, great variability is also found in the hours of deliberate practice accumulated to reach expert performance between different sports. For example, international level wrestlers had accumulated 5,882 hours of practice, international level soccer players had accumulated 7,449 hours of practice while international level field hockey players had accumulated 10,237 hours of practice. Also, great variability is found between athletes in the same sport (Duffy et al., 2004; Law et al., 2007). The variation in the hours of deliberate practice between and within sports questioned the central importance of deliberate practice on the development of expertise. Hambrick et al. (2014) re-analysed the findings of different studies into the effect of deliberate practice on the development of expert performance in chess and music. Results demonstrated that only 34.0% of the variance in chess performance can be explained by deliberate practice and only 29.9% of the variance in music performance (Hambrick et al., 2014). With the use of a similar approach, a meta-analysis was conducted to calculate the percentage of variance in sports performance explained by deliberate practice (Macnamara, Moreau, & Hambrick, 2016). For the sub-elite level, deliberate practice explained 19% of the variance of performance and for the elite level, deliberate practice only explained 1% of the variance of performance. According to Macnamara et al. (2016) other factors such as genetics, playful sport activities, multiple sport activities as well as psychological traits could account for differences in sport performance. Although the deliberate practice debate is mainly focused on the type of practice, Ford, Coughlan, Hodges and Williams (2015) argued that elite athletes engage in activities to improve their performance and termed this as the *deliberate environment*. In the deliberate environment, athletes plan and organise their personal and sporting life to optimise their competition performance. The amount of hours spent in this environment is suggested to increase from adolescent to adulthood (Ford et al., 2015).

2.3.3 Developmental Model of Sport Participation

Bloom (1985) described three different learning stages in the development of expert performers while Ericsson et al. (1993) reported a positive relationship between the hours of deliberate practice and expert performance. The work of Bloom and Ericsson et al. formed the basis for a critical study into the influence of families on the developmental pathways of expert athletes (Côté, 1999). The families of four expert athletes were interviewed about how they dealt with the three types of constraints on talent development (motivation, effort and resources) and how it affected the family dynamics. Côté (1999) reported three stages of sport participation: sampling years, specialising years and the investment years. In the sampling years, it was posited that children get involved in sport activities through their parents and the purpose of such engagement is to have fun and get familiar with various sports. The activities during this stage of sport participation are fun and enjoyable, intrinsically motivating, led by the child and often involves modified versions of the competition format of the sport to meet their need and are defined as *deliberate play* (Côté, 1999; Côté & Hay, 2002). At some point, parents seem to recognise that their child has talent for sports and from that point on, children start to focus more on one or two sports and start more sport-specific training. When the specialising years start, somewhere around the age of 13, parents start to commit to their child financially as well as the time they invest in their child's pursuit of sport. Through this commitment, parents also develop a more thorough interest in their talented child. Next to the commitment of the parents, children start to commit to their sport around the age of 15 when the investment years start. In this phase of talent development, talented athletes focus on their main sport and commit to an enormous amount of intense practice to improve performance and parents show even greater interest in their talented child and this leads to different behaviour towards each of their children. From the findings of the interviews on the role of families on the development of talented athletes, Côté offered the developmental model of sport participation (DMSP) (see Figure 2.2). Although the DMSP of Côté shares similarities with the three stages of learning model of Bloom, clear differences are apparent. Firstly, the model of Côté is specially designed for sports and makes a clear distinction in the type of practice that is undertaken by athletes in the different stages. The sampling years are characterised by more deliberate play than deliberate practice, the specialising years are characterised by relatively equal amounts of deliberate play and deliberate practice while the investment years are characterised by more deliberate practice than deliberate play. Secondly, the model of Côté only describes an athlete's pathway until the age of 18 in comparison to the model of Bloom, who describes the entire career of an athlete in his model. By doing this, Côté's model is generally more in line with the talent development process in sport.

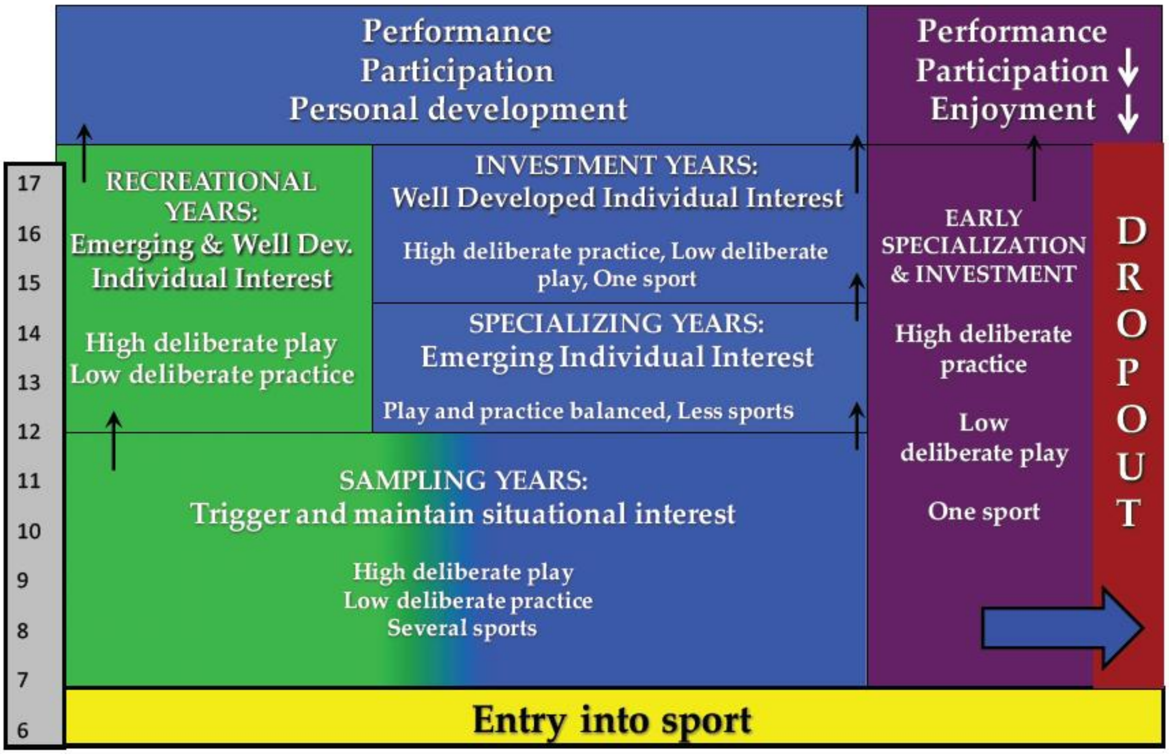

Figure 2.2. The developmental model of sport participation (DMSP) reproduced from Côté, Baker and Abernethy (2007).

The work of Côté (1999) also contributed to the debate about the contribution of deliberate practice to the development of expert sport performance. As mentioned above, Côté promoted a developmental pathway that starts with deliberate play activities in the sampling years and slowly moves towards more deliberate practice activities in the investment years (see Figure 2.2). Indeed, studies suggest that early specialisation is detrimental for sport success and sport participation and argue that early diversification and deliberate play is key to sport success in sports where peak performance occurs after maturation (Baker, 2003; Côté, Lidor, & Hackfort, 2009; Wall & Côté, 2007). This statement is supported by the developmental activities of German field hockey players (2012 Olympic Champions and national level) (Güllich, 2014). While Olympians and national level players reported a similar amount of field hockey specific training, the Olympians reported a greater amount of involvement in other sports compared to national level players and the Olympians specialised in field hockey at an older age. Consistent findings for the later onset of specialisation are shown for skilled and less skilled volleyball players (Coutinho, Mesquita, Fonseca, Côté, 2015).

Supportive findings for the benefits of sampling multiple sports were reported by Bridge and Toms (2012) who demonstrated that children who sampled more sports at the age of 11, 13 and 15 reached a higher level of competition between the age of 16 and 18 years. The benefits from accumulating practice hours in other organised sports are also apparent on the development of decision-making skills in Australian football (Berry, Abernethy, & Côté, 2008). Expert decision-makers had spent more time participating in deliberate play activities and other invasion games than the non-expert decision-makers. Furthermore, negative relationships between early specialisation and the development of sport performance have been reported (Read, Oliver, de Ste Coix, Myer, & Lloyd, 2016; Wall & Côté, 2007). Retrospective data of active ice-hockey players and those who dropped-out revealed that the players who dropped-out started off-ice training at a younger age and this form of early specialisation was detrimental for their development (Wall & Côté, 2007). Early specialisation and the increased volume of training are also associated with an increase of injury risk (Jayanthi, Pinkham, Dugas, Patrick, & LaBella, 2013). A linear relation between training volume and risk of injury was found in sports such as tennis (1.5 times more risk for specialising athletes) and baseball (3.5 times more risk for pitches who pitched >100 innings per year).

2.3.4 Early engagement hypothesis

An alternative talent development approach has been proposed by Ford, Ward, Hodges and Williams (2009) and consists of a mix of the early specialisation and early diversification approaches: the early engagement hypothesis. This hypothesis suggests that successful athletes do engage in their main sport at a young age and invest in an extensive amount of deliberate play activities during childhood before starting to spend more time in deliberate practice hours during adolescence. It is argued that sport-specific play activities significantly contributed to sporting success when supported by a great amount of sport-specific practice (Ford et al., 2009). The early engagement hypothesis differs from Côté's model as it is argued that only sport-specific deliberate play contributes to sporting success and not just any deliberate play. Supportive findings for the early engagement hypothesis were reported by expert youth soccer player who had invested significant more hours in soccer practice and soccer play activities then less-successful players while no differences in invested hours in competition and other organised sports were reported (Ford & Williams, 2012; Ford et al., 2012; Salmela, Marques, & Machado, 2004).

2.3.5 Differentiated Model of Giftedness and Talent

The amount and type of practice has been the major focus of the talent development models of Bloom (1985) and Côté (1999) and obviously is a central feature of Ericsson et al. (1993) deliberate practice approach. In these developmental models of sport expertise, a limited range of factors that might influence this talent development process are presented. Another model that describes the influence of these and other factors is the Differentiated Model of Giftedness and Talent (DMGT) of Gagné (2004). In this model, detailed information about the development process is explained as well as potential catalysts of the talent development process (see Figure 2.3). A clear distinction is made between being gifted and being a talent. Giftedness is described as having a natural ability that puts a child in the best 10% of their age in a specific domain while talent is the result of a systematically developed natural ability in a specific domain putting the person in the best 10% of his/her field. Being talented is the result of a development process (learning) and as a result, some athletes can be identified as a talent at a young age and then loose the label 'talented' due a decrement in their progress compared to other athletes. The development of the natural abilities into well-trained skills can be influenced by factors such as maturation and the type and volume of practice (Côté, 1999; Ericsson et al., 1993). Furthermore, the developmental process is influenced by three types of catalysts: intrapersonal and environmental catalysts and chance. Each of these factors can facilitate or hinder development. Intrapersonal catalysts refer to, for instance, physical, personality and motivational characteristics of a talent. These characteristics relate back to two constraints identified by of Ericsson et al.: motivation and effort. Environmental catalysts refer to influences from outside a person's power and this relates back to the resource constraint of Ericsson et al. and the family influence described by Côté. The last catalyst is chance, which influences the occurrence of natural abilities as well as the intrapersonal and environmental catalyst. Altogether, the DMGT is a highly dynamic model which describes the potential influential factors on the developmental process of a gifted athlete.

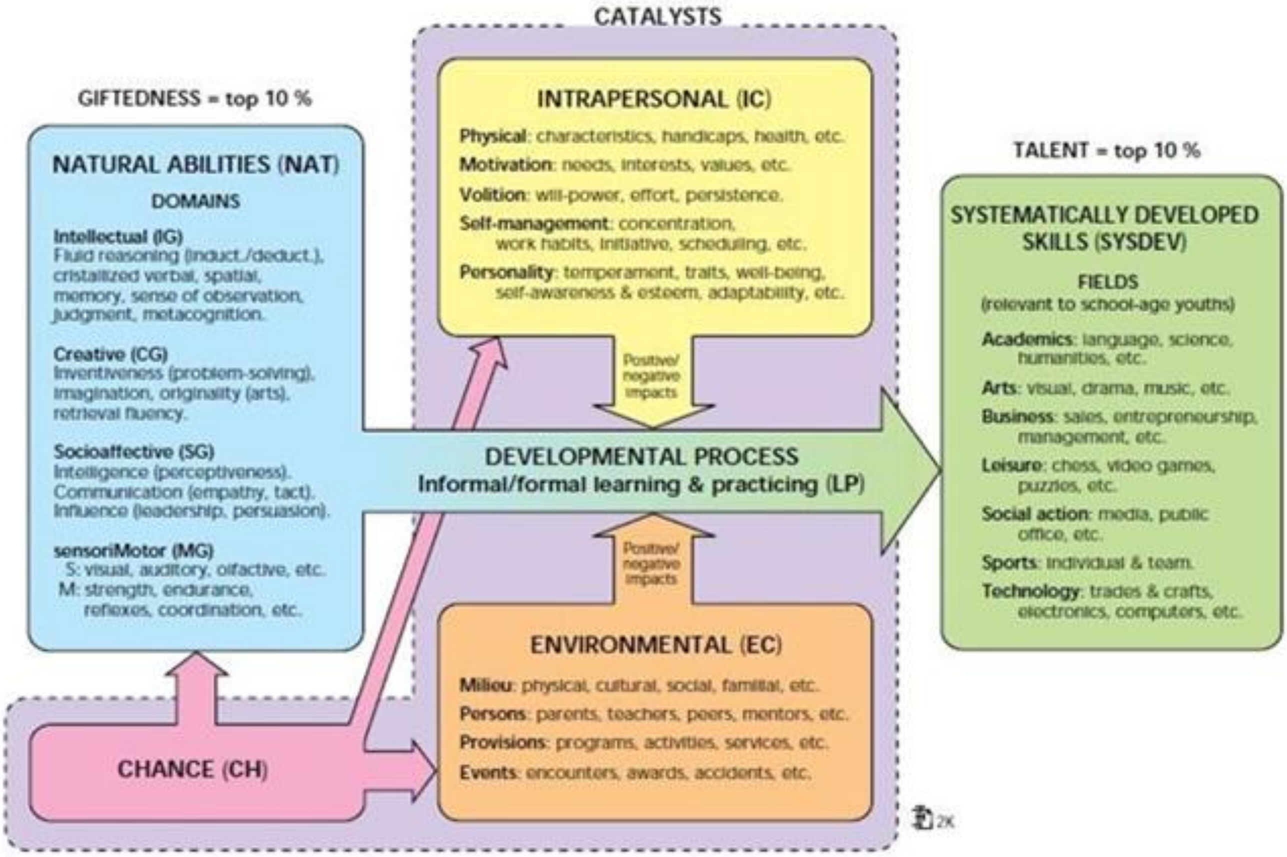

Figure 2.3. The Differentiated Model of Giftedness and Talent (DMGT) of Gagné (2004).

Although the DMGT provides a dynamic and holistic view of the talent developmental process of sport expertise, the model has several limitations. According to the DMGT, characteristics such as motivation, self-regulation and personality only function as catalysts in the model and it could be argued that the model suggests that a person's ability is fixed. Therefore, it is suggested by Yun Dai (2004) that this definition of giftedness is incorrect as it proposes a *fixed mindset* which is shown to be detrimental for the development of someone's ability (Yeager & Dweck, 2012). Secondly, the idea that a person's ability is fixed, would propose that genetics set the limits and this would set back the debate between nature and nurture (Guenther, 2004). Thirdly, it is argued that the DMGT is based on existing literature and that the applicability of the model is not yet verified in a practical setting (Gublin, Croser, Morley, & Weissensteiner, 2013).

2.3.6 FTEM framework

From the discussed talent development models, it can be noticed that the focus of each model is only on one aspect of talent development rather than a holistic approach (Gublin et al., 2013). A talent development framework with a more holistic approach was established by Australian practitioners. This framework consisted of four macro stages and ten micro stages of sport participation: Foundation (F1, F2 and F3), Talent, (T1, T2, T3 and T4), Elite, (E1 and E2) and Mastery (M) (Gublin et al., 2013). The model does not solely focus on expert athletes as the outcome of talent development but also focuses on sport participation in general (see Figure 2.4). In the Foundation stage, the focus is on attaining foundational movement skills through an early exposure to a wide range of movement activities and when children are competent movers, through the use of informal play and games. The next step in the development of skills is a more sport-specific environment where children make a commitment to a specific sport. The majority of athletes will spend their lifetime in this phase of development and perform their sport on a recreational level. Other athletes will be identified as talented based on sport-specific characteristics and move on to the Talent phase of development (T1). The key aspect for these talented athletes is to confirm their talent during a talent pathway or training program where expert coaches and facilities become more accessible. The athletes are now committed to more sport-specific training which relates back to more deliberate practice and is somewhat analogous to Côté's investment years. The last phase of the Talent stage is being awarded or drafted into a professional team or national squad that will greatly accelerate development (T4). By this time, most athletes are considered as professional and expert athletes in their sport and the last stages of development are attributable to the achievements they make during world-class tournaments (E2 and M). Although the FTEM framework represents a linear model, it is emphasised that talent development is non-linear and athletes can skip different stages or return to a previous stage based on their own performance or the performance of other athletes (Gublin et al., 2013). Altogether it can be concluded that the FTEM framework provides a talent development framework that emphasises the dynamic character of talent development. Secondly, the framework focuses more on performance related stages instead of age related stages as this is different per sport and individual.

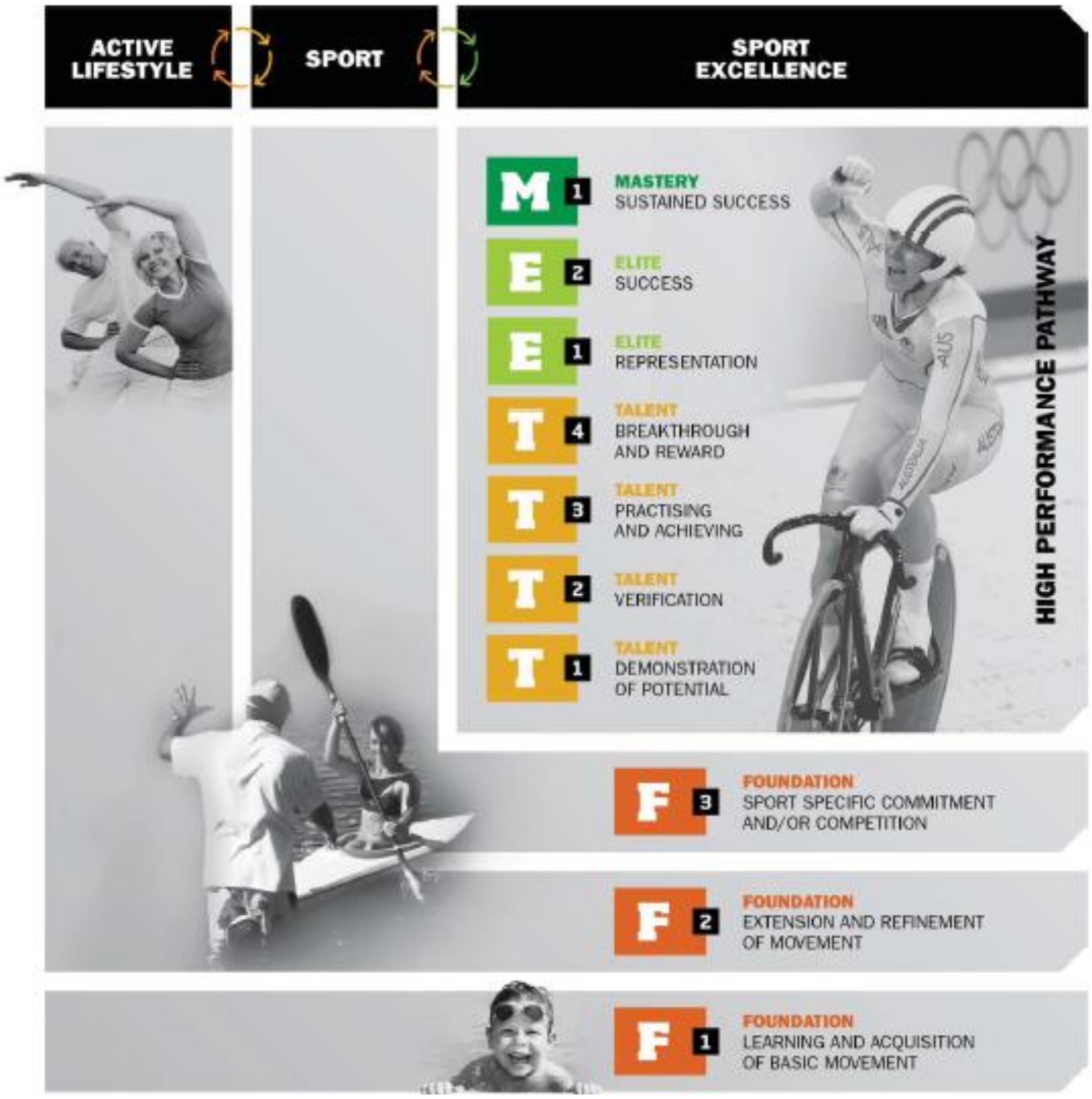

Figure 2.4. The Foundation, Talent, Elite and Mastery (FTEM) framework of Gublin et al., (2013).

2.3.7 Comparison of the described talent development models

Comparing the different talent development models, it is evident that there are clear differences between the models but that there are also similarities. Although it is described in different ways, according to all models, talented athletes possess natural abilities and have to develop these natural abilities in a systematic way to be able to compete at an expert level. It is this development process where the models differ most. According to Bloom (1985) and Côté (1999) this process consists of three different stages that are chronologically based while Gublin et al. (2013) distinguishes a total of 10 different stages that are performance based. Also, the development process is presented as linear in the models of Bloom (1985), Côté (1999) and Ericsson et al. (1993) where skills are developed in a systematic way through a great amount of training. A more dynamic nature of talent development is presented by Gagné (2004) where personal and environmental factors influence the development process. This dynamic nature of talent development is also highlighted by Gublin et al. (2013) and in a recent review of Rees et al. (2016). In this review paper, evidence is presented about factors influencing the development of expert performance and three key components are distinguished: the performer, the environment and practice and training. These key components are divided into many smaller components that are of influence on the development of expert performance. This idea of talent development shares a lot of commonalities with the model of Gagné. The key component 'the performer' corresponds with the natural abilities and intrapersonal catalyst from the DMGT model. The key component 'the environment' corresponds with the environmental catalyst from the DMGT and finally, the key component 'practice and training' mainly corresponds with the development process of the DMGT model. The models of Gagné and Rees et al. mainly discuss potential factors that can influence the developmental process of a talented athlete, while Bloom, Côté and Ericsson et al. predominately focus on the amount and type of practice that influences the developmental process of an athlete, which corresponds with the key component 'practice and training' of Rees et al. One major difference between the model of Gublin et al. and the other talent development models is that the model of Gublin and colleagues is led by the performance of athletes while the other models focus on the developmental process that eventually lead to certain performances. Thus, in the FTEM framework performances are leading while in the other models, performance is the result of the interaction between practice and certain natural abilities.

Some of these differences and similarities are of influence on talent identification and talent development policies of sport governing bodies and their idea of what a 'talented athlete' is and should do. The developmental process of an athlete is obviously very sport-specific and therefore, different models fit better for specific sports. For example, some believe that when the peak of performance is at a younger age, an early diversification model might not be as suitable as for a sport where the peak of performance is at a later age. However, anecdotal evidence suggests that the opposite could also lead to expert performance and the underlying mechanism remains unclear. Indeed, this and more influential factors will be discussed in relation to the identification and development of talent in the sport of field hockey in the next section.

2.4 Performance testing as part of talent identification

For sport governing bodies such as Hockey Australia, it is important to have an appropriate and clear talent development policy to create guidelines for the talent identification and the development of players. Policies and definitions of what 'talented' athletes are and how 'talented' athletes should develop their skills are influenced by the adopted talent development model. In line with Bloom (1985), Côté (1999) and Gublin et al. (2013), a recent paper presented recommendations for sport governing bodies on youth sport programmes (Côté & Hancock, 2016). Three key aims were discussed: performance, participation and personal development. For most of the invasion games, such as field hockey, the age of peak performance is in the late 20's (Côté et al., 2009) and therefore, predicting long-term success at a very young age is very unreliable. For a sport such as field hockey, even though expert performance is the ultimate goal of development, young players should get enough opportunities to participate in fun and enjoyable activities during the younger years. This enjoyable first experience with sport will increase the participation of children in sport as studies show that a positive first experience with sport increases the chance on long-life sport participation, with all its benefits (Côté et al., 2009). Through the playful experience of children without the focus on performance, children will gain social skills and other life skills that are useful for later in life. It is of great importance that these three aims; performance, participation and personal development are equally weighted in a sport policy (Côté & Hancock, 2016). In contrast, recommendations based on the work of Ericsson et al. (1993) would focus on early engagement and early specialisation through the amassing of a great amount of deliberate practice through great effortful. However, recommendations would be solely focused on the amount and type of practice while it is clear from the talent development model of Gagné (2004) and the review paper of Rees et al. (2016) that there are many more factors influencing the development process of an athlete which increases the complexity of talent identification.

Historically, talent identification has been focused on anthropometric and physiological performance measures, as it was believed that these measurements were correlated to sport success. One of the first studies to examine the relationship between body composition and sport performance was conducted during the 1968 Olympic Games in Mexico (de Garay, Levine & Carter, 1974). Results demonstrated that there was a strong correlation between body composition and the type of sport. Consistent findings were reported by Leone and Lariviere (1998) who discriminated tennis players, figure skaters, cyclist and gymnasts based on their anthropometric variables. Relationships between anthropometric variables and sport performance were found for gymnastics (Claessens, Lefevre, Beunen, & Malina, 1999), basketball (Hoare, 2000), weightlifting (Fry et al., 2006), rowing (Mikulic & Ruzic, 2008) and ice-hockey (Burr et al., 2008). However, the predictive value of these measurements was very low and associated with a range of problems. This and several other limitations of talent identification using performance testing is discussed by Lidor, Côté and Hackfort (2009) and Abbott, Button, Pepping and Collins (2005). Firstly, one of the main limitations of current performance testing batteries is that physical attributes are only one aspect of the many factors that make an athlete talented and these physical attributes are unstable characteristics. Two potential influential factors on the performance of physiological tests are training history of an athlete and their maturation status and these factors are often overlooked during talent identification (Abbott et al., 2005; Lidor et al., 2009). Furthermore, it is argued that the predictive value of these physical attributes is not clear as several studies indicate that there is no correlation between physical attributes and player ranking or future sporting success (Lidor et al., 2005). Secondly, there is a lack of consideration of the perceptual-cognitive components of skill such as decision-making and anticipation (see Farrow, 2012 for an exception). Thirdly, it is suggested that we behave as a complex system and therefore, measuring only a few factors of that system, won't provide a detailed overview of the abilities of that system. So talent identification based on only a few performance variables lacks information about the ability and potential of an athlete. This situation can be improved with the adoption of multi-dimensional talent identification approaches (Abbot et al., 2005; Burgess &

Naughton, 2010; Lidor et al., 2009). Acknowledging the above issues, it is argued that a well-constructed test battery that considers more than simply physical precocity can be a very useful tool for coaches to assess their athletes' skills and monitor their development as well as predicting or identifying a players potential.

In line with the recommendations based on the limitations of performance testing batteries provided by Abbott et al. (2005) and Lidor et al. (2009), a multi-dimensional approach to talent identification has been applied to field hockey, where anthropometric, physical, technical skill, tactical skill and psychological characteristics of players of different levels were measured (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Keogh, Weber, & Dalton, 2003; Nieuwenhuis, Spamer, & van Rossum, 2002). Findings revealed that elite Dutch field hockey players outperform their sub-elite peers on sprint capacity, dribble ability, tactical skills and motivation (Elferink-Gemser et al., 2004). Similar findings were found for South African field hockey players, where elite players outperformed their less successful peers on endurance and sprint capacity, passing accuracy, dribble ability and motivation (Nieuwenhuis et al., 2002) while Australian state level players scored better on body fat percentage, endurance and sprint tests, dribble ability and shooting accuracy than their club level peers (Keogh et al., 2003). Altogether, it can be concluded that sprint and endurance capacity, dribble ability and motivation are discriminating factors between elite and non-elite level youth field hockey players. Although these studies focus on multiple performance characteristics, a limitation is that the main focus on these tests are still on anthropometric, physiological and sport-specific technical skills. In the studies of Elferink-Gemser et al. (2004), Niewenhuis et al. (2002) and Keogh et al. (2003) respectively 10 out of 19, 19 out of 19 and 32 out of 41 performance variables were anthropometric, physiological and/or sport-specific technical skills. Obviously there are multiple other skills contributing to performance in field hockey and, indeed, a talent identification testing battery should account for this (Abbott et al., 2005; Lidor et al., 2009; Williams & Reilly, 2000).

The importance of a multi-dimensional approach to talent identification is also highlighted by a systematic review into the determinants that influence playing level in racquet sports (Faber et al., 2015). Using the DMGT framework of Gagne (2004) as guiding talent development model, Faber et al. (2015) provide an extensive list of natural abilities and intrapersonal catalysts that have been shown to be discriminative between elite and non-elite racquet sport players. Although most of the different domains of natural abilities of the DMGT were covered, it was clear that a great proportion of studies have focused on the physical abilities of athletes and an under-represented number of studies focused on creative and social skills (Faber et al., 2015). Thus, future work should focus on all domains of the DMGT to provide a holistic view of an athlete's talent. The importance of focussing on a wide range of performance characteristics during the talent identification process is highlighted in recent work investigating Australian football (Woods, Raynor, Bruce, McDonald, & Robertson, 2016). The predictive value of performance testing was examined for the selection of U18 players. A total of 42 talented and 42 non-talented players completed a multi-dimensional testing battery and the predictive value of different performance characteristics was calculated. Findings revealed that a testing battery consisting of just physical performance measurements was able to predict 84.2% of the players correctly, a testing battery of just sport-specific technical skills was able to predict 89.4% correctly, a testing battery consisting of just perceptual-cognitive performance measurement was able to predict 89.0% correctly while a combination of the three testing battery was able to predict 95.4% of the players correctly (Woods et al., 2016).

The recommendations proposed by Abbott et al. (2005) and Lidor et al. (2009) to improve the use of performance testing batteries and the findings of Faber et al. (2015) and Woods et al. (2016) emphasise the importance of a multi-dimensional approach to talent identification. Expert performance of invasion team-sports is multi-faceted and as such, accounting for this during performance testing will improve the predictive value of talent identification. What kind of performance characteristics influence playing level in field hockey will be discussed in the next section.

2.5 Performance characteristics in field hockey

As mentioned in the previous section, expert performance of invasion team-sports is multi-faceted and according to the DMGT framework of Gagné (2004) there are different factors (catalysts) influencing the development of sports expertise. In this section, with field hockey as the exemplary sport, the influence of intrapersonal catalysts such as the anthropometrics, physical capacity and self-regulatory skills of athletes will be discussed as well as the influence of sport-specific technical skills and perceptual-cognitive skills. Finally the influence of type and amount of practice will be discussed.

2.5.1 Anthropometrics

With the first official Olympic Games in 1896, sporting events became bigger and attracted strong interest from the public as well as from scientists. Since the 1928 Olympic Games held in Amsterdam, scientists were interested in the generic body characteristics of the athletes competing at this sporting event, which at that time, attracted 2883 athletes from 46 countries. Although most of the testing was very simple and consisted of measuring height, weight and age, more extensive measurement into the characteristics of the body were completed in following years. One of the most extensive studies on the composition of athletes' bodies was conducted during the 1968 Olympic Games in Mexico. A team of researchers, supervised by Alfonso L. de Garay, examined a total of 1265 Olympic athletes from 92 countries and compared their results against a control group of 370 Mexican non-athletes (de Garay et al., 1974). Results showed that the body size of athletes from certain sports differed significantly whilst other sports shared a similar advantageous body type. There was a strong relationship between the body type of an Olympic athlete and the specific sport in which they performed and therefore it was suggested that there are clear physical body types for optimal performance in Olympic events. The findings of this study developed the idea of optimal anthropometric characteristics for different sporting events and also the idea that talent identification based on anthropometric characteristics could be successful for future sporting success.

Several studies examined the influence of anthropometric characteristics on the performance level of field hockey players and determined that body composition doesn't seem to have a major influence. A study conducted in South Africa compared the two top teams (n=25) and the two bottom teams (n=27) of the U15 North West Province competition (Nieuwenhuis et al., 2002). A total of 17 different anthropometric variables were measured and findings revealed one skinfold measurement differed between the performance levels. The bottom team players had significantly more fat on the frontal thigh. This is also somewhat consistent with Keogh et al. (2003) who showed that club level players had a significantly higher percentage of body fat compared to the representative players. In two Dutch studies, where anthropometric variables were compared between elite and sub-elite players of three different age groups (12-14 years, 15-16 years and 17-19 years), no anthropometric differences between playing level were found for any of the age groups. However, the discriminant function analysis for the older age group showed that height, in combination with accumulated field hockey practice and dribble skills, significantly contributed to the model that could classify 78.7% of the players correctly (Elferink-Gemser et al., 2004; Elferink-Gemser, Starkes, Medic, Lemmink, & Visscher, 2011). Altogether it can be concluded that there is no clear advantageous body type for field hockey and that there are big differences in the variables measured by the different studies. A total of 17 different anthropometric measurements were taken in the study by Nieuwenhuis et al. (2002), whilst only three anthropometric measurements were recorded by Keogh et al. (2003) and Elferink-Gemser et al. (2004, 2011).

2.5.2 Physical capacity

The motto of the Olympic Games is ‘Citius, Altius, Fortius’, which means faster, higher and stronger. Although these factors are of major importance in sports such as track and field and swimming, their importance is also established in team-sports such as field hockey. Bhanot and Sidhu (1981) completed one of the first studies into the physical capacities of field hockey players when they examined the anaerobic power of basketball, field hockey, soccer and volleyball athletes. Results demonstrated that field hockey and soccer players recorded a higher vertical velocity compared to basketball and volleyball players whilst volleyball players outperformed all other players on anaerobic power. In a latter study, the anaerobic power of 90 field hockey players of different playing positions was compared (Bhanot & Sidhu, 1983). Results demonstrated that goalkeepers recorded the highest vertical velocity as well as anaerobic power while forwards recorded the lowest vertical velocity and anaerobic power. A more advanced description of the physical demands of field hockey was described by Reilly and Borrie (1992), who determined that field hockey could be indicated as ‘heavy exercise’. Field hockey was played at a very high pace and on average, players were performing to 78% of their VO2max during a whole game (Boyle, Mahoney, & Wallace, 1994). In more recent years, Global Positioning Systems (GPS) have been used to measure the physical demands of field hockey

(Macleod, Morris, Nevill, & Sunderland, 2009). Several studies showed that playing at the highest international level requires a high level of conditioning as players cover a large distance per game and have to repeat multiple high-intensity bouts per game (Jennings, Cormack, Coutts, & Aughey, 2012b; Lythe & Kilding, 2011; Macutkiewicz & Sunderland. 2011). A comparison between Australian international and national players revealed that physical capacity could discriminate between high-level competitions as international players covered more distance per game and also covered more distance in high speed running (Jennings, Cormack, Coutts, & Aughey, 2012a). Taken together, it can be concluded that speed and endurance are important physical abilities to be able to perform at the highest level of competition and therefore, young field hockey players who possess these abilities could have an advantage over their peers when being selected for a representative team.

The importance of physical abilities on the performance level in youth field hockey was determined by comparing the players of successful and non-successful teams of an U15 competition. Players were asked to perform several physical tests and results showed that the players of the two top teams scored significantly higher on the multistage shuttle run test and a 40-metre sprint test (Nieuwenhuis et al., 2002). Further exploration with the use of a discriminant function analysis showed that sprint time and agility time were two of the eight variables that significantly contributed to the prediction function. With the use of this prediction function, 95.2% of the top team's players were classified correctly and 85.7% of the bottom team's players were classified correctly. The difference in sprint ability is also present in a Dutch cohort of talented and non-talented players of U15 (Elferink-Gemser et al., 2004). However, no significant difference in endurance capacity was apparent between the two playing levels. Keogh et al. (2003) compared regional and club level players performing a range of physical tests and found that the regional players outperformed their club level peers on 10-metre sprint, 40-metre sprint, multistage shuttle run test, vertical jump, long jump and agility. The superior score of the talented players on the sprint tests and the multistage shuttle run test were consistent with findings of Nieuwenhuis et al. (2002); however, the differences in vertical jump and agility were not consistent. A possible explanation for these differences could be related to the age of the players; the players were on average 6 years older in the Keogh et al. (2003) study. This could potentially suggest that with an increase in age, physical abilities become more important in field hockey. This argument is supported by findings of Elferink-Gemser et al. (2011) who compared elite and sub-elite players of two different age groups (12-14 years old and 16-19 years old). For sprint ability, the effect size (Cohen's *d*) between playing level for young players was 0.02 while the effect size between playing level for older players was 0.09. For endurance level, the effect size between playing level for young players was 0.06 while the effect size between playing level for older players was 0.15. Although the effect sizes are relatively small, a consistent increase for both variables is apparent. From these studies it is clear that sprint ability and endurance capacity are discriminating factors between talented and non-talented field hockey players. Seemingly, with an increase in age, the differences in physical capacity increase potentially due to an increase of speed of the game. Therefore, the physical demands of the game become higher and accordingly players should increase their physical capacity.

2.5.3 Sport-specific technical skills

The modern game of field hockey was founded in the early 19th century in England and since then several rule or equipment changes have been introduced. The International Rules Board was founded in 1900 and field hockey had its first appearance in the 1908 Summer Olympics of London, United Kingdom. However, only in 1973 was an official international rule book available and since then, field hockey all over the world has been played in the same manner. Although the rules of field hockey were not consistent in different countries, an attempt to quantify field hockey skill was made (Schmithals & French, 1940). Unfortunately no full text version of the document was found, but from the first page it is clear that the authors made an attempt to quantify six important skills in field hockey to be able to discriminate between different playing levels:

1. Dribble, dodge, circular tackle and drive.
2. Drive for goal.
3. Fielding and drive.
4. Push pass.
5. Drive for distance.

6. Receiving ball from team mate.

Although no results of the tests are available, it is interesting to note that the test focused on a wide range of field hockey specific skills. Some of these skills are also present in the Henry-Friedel Field Hockey Test (HFFHT) (Henry, 1970) (see Figure 2.5), which is a modified version of the Friedel Field Hockey Test developed by Friedel in 1956. In this test, players are tested for their speed, their ability to receive the ball on the run, their dribble abilities and their hitting abilities. Players had to perform 10 trials and a speed and accuracy score was given. The speed score was the sum of the times for all 10 trials and the accuracy score the sum of the accuracy scores of all 10 trials. It can be argued that the speed score of the HFFHT is majorly influenced by the running speed of the participants and less influenced by their dribbling skill. The opposite is apparent in the Chapman-ball control test where players are tested for their ball-handling skills in a stationary manner. In this test, players have to position themselves in front of two circles (inner and outer circle) and move the ball as fast as possible into or through the inner circle in 15 seconds (Chapman, 1982) (see Figure 2.6). A point is awarded for every ball that is tapped into or through the inner circle and brought outside the outer circle. Although this could be seen as a pure score of dribbling ability, the task itself is not very game-specific. The authors also suggest not using this test as the sole instrument to determine a player's skill level.

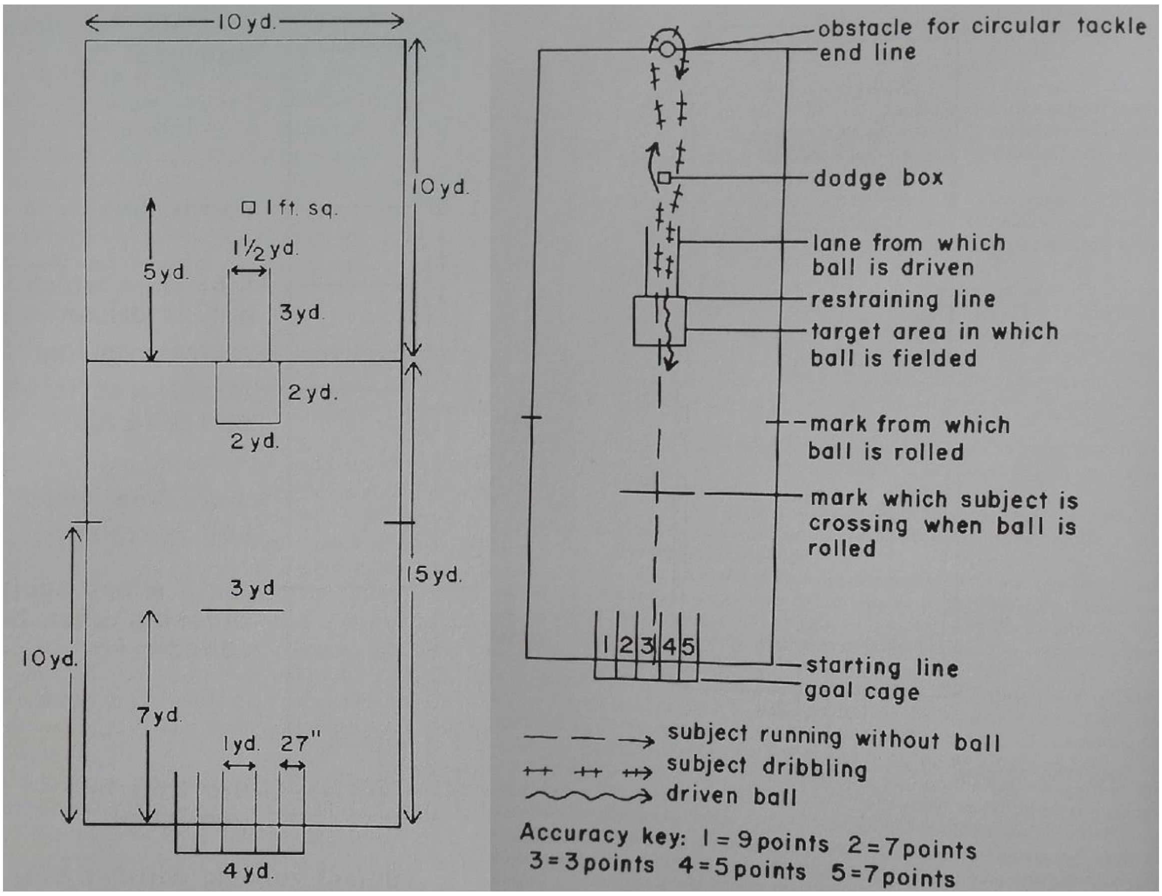

Figure 2.5. The Henry-Friedel Field Hockey Test (HFFHT) of Henry, 1970.

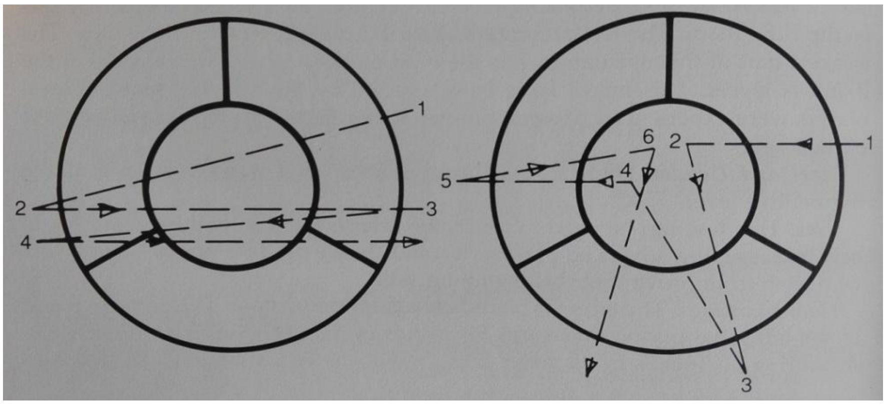

Figure 2.6. The Chapman-ball control test of Chapman, 1982.

In more recent years, several studies have aimed to find discriminating skill factors between talented and non-talented players. The technical skills of South African U15 female field hockey players were determined with the use of an agility-dribble test, metre stick test, several push and hit tests and a slalom dribble (Nieuwenhuis et al., 2002). More talented players outperformed the less talented players on the agility-dribble test, the metre stick test, push for accuracy through air and the slalom dribble. All tests that could be considered as measurements of ball handling/dribbling skills yet only one of the six accuracy tests discriminated between skill levels. These results suggest that ball handling/dribbling skills are more important than the ability to pass or hit accurately to perform at a high level of competition. The importance of ball handling/dribbling skills is also reported by Keogh et al. (2003) who reported that regional players completed the Illinois Agility Run (IAR) while dribbling with the ball faster than their club level peers. Also, regional players performed better on the shooting for accuracy test. In this test, players had to shoot, push or flick towards designated areas in the goal. Regional players had an average shooting percentage of 37.5% while club players had an average of 18.3%. A possible explanation for the low shooting averages could be explained by the location of shooting positions and the scoring areas. Even though players could score a goal they still didn't get a point awarded for an attempt. However, the test seems to be able to discriminate between players and it seems unlikely that a ceiling effect would occur.

Although the ability to pass or hit the ball accurately seems to be important and able to discriminate between talented and non-talented players, this skill was not measured by Elferink-Gemser et al. (2004) and Elferink-Gemser et al. (2011). Elite and sub-elite U16 players had to perform a slalom dribble while running with the ball and results revealed that elite players were able to complete the slalom dribble significantly faster than their non-elite peers (Elferink-Gemser et al., 2004). Further exploration with a discriminant function analysis revealed that the slalom dribble completion time significantly contributed to the discriminant function for both age groups. Similar findings were reported by Elferink-Gemser et al. (2004) who reported that slalom dribble performance significantly contributed to the discriminant function. Both studies highlight the importance of ball handling skill for field hockey performance and selection predictability.

In summary, it can be concluded that field hockey specific technical skills are able to discriminate between talented and non-talented players and that performance on technical skills tests positively relates to performance levels in field hockey. From the results of the different studies it is clear that ball handling while running is one of the most important technical skills in field hockey and passing/hitting skill should also be incorporated in a testing battery to identify field hockey talent.

2.5.4 Perceptual-cognitive skills

It is clear from the previous sections, that the physical capacity and sport-specific technical skills are of major importance to compete at the highest international level in field hockey and these characteristics are able to discriminate between talented and non-talented players (Elferink-Gemser et al., 2004; Keogh et al., 2003; Nieuwenhuis et al., 2002). However, in a fast-paced sport such as field hockey, decision-making is a key skill to possess to be able to compete at the expert level. When adopting a cognitive approach, the complexity of decision-making is clear from the seven staged model of decision-making presented by Farrow and Raab (2013):

1. The decision-making situation *presents* itself for the player.
2. The player *identifies* his action capabilities in this situation and prioritises his goals.
3. From these priorities, the player *generates* possible actions.
4. The player then *considers* his actions to be able to achieve his primary goal.
5. The player then *selects* his optimal action.
6. After the selection, the player *initiates* the action physically.
7. The player then *evaluates* the outcome of his action in relation to this primary goal.

It is argued that expert performers have to go through these seven stages quickly and as efficiently as possible to make the right decision while being under enormous time pressure. However, when adopting an ecological approach, it is argued that the coupling between perceptual information from the environment and action of the player will guide decision-making. Interestingly, perceptual-cognitive skills are often omitted from a testing battery for talent identification yet ironically it is also often cited as one of the main limitations of current performance testing approaches (Burgess & Naughton, 2010; Farrow, 2012; Lidor et al., 2009). Indeed, there is an extensive body of research providing evidence for the superior perceptual-cognitive skills of expert performers over their non-expert peers for anticipation (Müller & Abernethy, 2012), decision-making (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007) and pattern recognition (Gorman, Abernethy, & Farrow, 2012). Anticipation is referred as the ability to "read" game situations or opponent's movement by extracting information from the environment or kinematic information from the opponent to help prepare a response (Williams, 2009). Decision-making is referred as the ability to select the next best move and execute this movement as accurately and quickly as possible (Vaeyens et al., 2007) while pattern recognition is the ability to recognise and recall key features of domain-specific patterns in the performance context (Gorman et al., 2012). In field hockey decision-making and anticipation have been a focus of interest. For example, Starkes (1987) examined the national women field hockey team of Canada (elite), a field hockey varsity team (sub-elite) and novice field hockey players on a range of perceptual-cognitive 'hardware' and 'software' measurements. Findings revealed that elite and sub-elite players did not have superior reaction time, coincident anticipation and no superior ability to track moving objects (i.e., hardware characteristics). However, elite players did possess superior field hockey game-specific pattern recall abilities, shot prediction abilities and elite players made more accurate offensive decisions (i.e., software characteristics). It is argued that these sport-specific perceptual-cognitive skills are developed through experience and training and are not the result of superior 'hardware' characteristics. Hence, sport-specific perceptual-cognitive skills aren't natural abilities but largely influenced by the amount and type of practice.

In an attempt to measure decision-making, Sunderland, Cooke, Milne and Nevill (2006) required players to dribble, pass and shoot a ball into a goal. 'Decision-making' time was defined as the time a player took to respond to a light that illuminated in the goal, triggered by crossing a laser beam, and stopped when the ball hit the goal. Players had to score on the opposite side of the goal where the light was on. Results showed a correlation of $r = 0.89$ ($p<0.0001$) between 'decision-making' time and coaches' rankings. Although Starkes (1987) and Sunderland et al. (2006) showed that perceptual-cognitive skills are important characteristics to perform at an expert level, it could be argued that the tasks used were not very representative of the field hockey environment. The influence of task stimuli on the superior perceptual-cognitive skills of expert athletes will be discussed in the next paragraph.

When measuring perceptual-cognitive skills of athletes, it is suggested that several features of the task stimuli can influence the differences between expert and non-expert athletes (Mann, Williams, Ward, & Janelle, 2007). Firstly, it is suggested that the task stimuli has an extensive influence on the differences in tests results of perceptual-cognitive skills. Findings have revealed that differences between expert and non-expert athletes were largest in field studies, followed by experimental designs where the task stimuli was displayed using video or static images (Mann et al., 2007). Secondly, it is suggested that the manner of response influences the differences between expert and non-expert athletes. The largest differences in perceptual-cognitive skills are apparent when perception and action are coupled (Farrow, 2012). Thirdly, it's reported that the perspective of the stimuli influences perceptual-cognitive expertise of athletes (e.g. aerial view of player's perspective). It was shown in soccer and water polo that perceptual-cognitive skills were superior in the aerial view while in basketball and netball, superior perceptual-cognitive skills were apparent in the player's perspective. It was suggested that this difference between sports was likely due to the specific patterns presented in each sport (Farrow, 2012).

It can be concluded from Starkes (1987) and Sunderland et al. (2006) that perceptual-cognitive skills in field hockey are able to discriminate between expert and non-expert athletes and that test characteristics should be sport-specific and representative of the normal field hockey environment with the coupling of perception and action (Farrow, 2012; Mann et al., 2007).

2.5.5 Self-regulation

It is clear from talent development models that expert performance is the result of natural abilities (gifts) and the development of these gifts through hours of practice. Firstly, the type of practice is of influence on the development of skills according to Ericsson et al. (1993) and Cöté (1999) and secondly, how athletes approach their training also influences the development of skills. To get the most out of a training session, it is suggested talented athletes have to be metacognitively, motivationally and behaviourally proactive in their own learning process (Zimmerman, 1986). Players who possess better self-regulatory skills take more control of their learning process to improve their skills during a training session. The training sessions are optimised in such a way that athletes prepare and motivate themselves for their training or performance, take control to optimise and monitor their own performance and evaluate their performance in the end which will influence their next action. Although not specifically named as 'self-regulation', the ability to take control over one's learning process is reported in the DMGT as one of the intrapersonal catalysts on the developmental process of talented athletes (Gagné, 2004). Self-management, motivation and volition are different means to improve the self-development of an athlete and self-regulation is a way of measuring this. Self-regulation can be measured by a self-report questionnaire that consists of six different subscales: *planning, self-monitoring, effort, self-efficacy, evaluation and reflection*. Planning refers to the awareness of how to approach a task, self-monitoring refers to the awareness of an athlete's own actions, effort refers to the willingness to reach the set goal, self-efficacy refers to how an athlete judges his own capabilities to perform an action, evaluation refers to the ability to assess the process as well as the outcome of a task after completion and reflection refers to the ability to appraise what is learned and use this knowledge to improve (Jonker, Elferink-Gemser, & Visscher, 2010; Toering, Elferink-Gemser, Jordet, Pepping, & Visscher, 2012).

Ericsson et al. (1993) advocated that athletes have to invest in an extensive amount of deliberate practice to reach the expert level in music, dance, academia as well as in sports. Deliberate practice refers to activities that consist of different processes: the athlete sets specific goals for the training, the training is highly structured, the chosen tasks are not inherently enjoyable and athletes self-monitor their performance to set new performance goals (Ericsson et al., 1993). Interestingly, according to several studies into self-regulation, athletes with exceptional self-regulatory skills approach their training in a similar way (Jonker et al., 2010; Toering et al., 2012; Zimmerman, 1986) and therefore it is suggested that the deliberate practice theory and self-regulation may in fact measure the same construct (Baker & Young, 2014; Tedesqui & Young, 2015). When athletes possess a great amount of self-regulatory skill, they will put in the necessary effort that will lead to skill improvement and they will monitor their own performance to set new goals. Coughlan, Williams, McRobert and Ford (2014) related deliberate practice theory to how expert and non-expert participate in a self-selected training session. Expert athletes predominantly practiced their weaker skill and showed greater improvement in this skill then their non-expert peers (willing to improve) and expert athletes also reported the training sessions as physically more demanding (more effort in training). Furthermore, verbal reports demonstrated that expert athletes reported more monitoring and planning statements indicating a greater mental effort than the non-expert group. The results of the verbal reports suggest that the expert athletes possess greater self-regulatory skills as they planned, structured and monitored their training more which led to greater skill improvement (Couglan et al., 2014). This self-regulation cycle will lead to a training session that is highly structured, requires effort and focuses on performance improvement (see Figure 2.7). Having great self-regulatory skills is therefore likely to lead to more deliberate practice sessions compared to athletes who don't possess great self-regulatory skills.

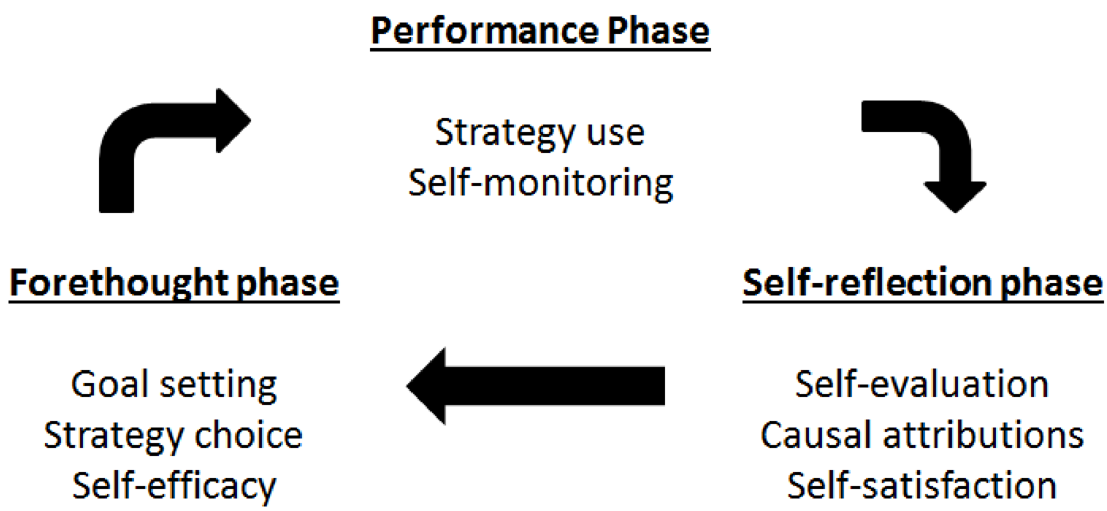

Figure 2.7. Self-regulation cycle and different subprocesses (adapted from Cleary & Zimmerman, 2001).

The influence of self-regulatory skills on playing level in youth soccer was examined by Toering, Elferink-Gemser, Jordet, and Visscher (2009). A total of 159 elite and 285 non-elite youth soccer players between the age of 11 and 17 years completed the self-regulation questionnaire. Elite players played for a professional soccer club while the non-elite players competed five divisions lower. Findings revealed that the elite players scored significantly better on *reflection* and *effort*. Scoring high on *reflection* increased the chance of playing at the elite level by 4.9 times and scoring high on *effort* increased the chance of playing at the elite level by 7.1 times than players who scored low on either subscales (Toering et al., 2009). In another study, the self-regulatory skills of international and national youth soccer players were compared (Toering et al., 2012). National level players played for a professional soccer club while international level players were selected for a representative team of the Dutch Soccer Association (KNVB). Results showed that international level players scored significantly higher on *reflection* than their national level peers. Similar results were found in a study that examined the influence of self-regulatory skills on playing level in team and individual sports (Jonker et al., 2010). A total of 113 individual athletes and 109 team-sport athletes between the age of 12 and 16 years completed the self-regulation questionnaire. From the 222 athletes, 78 athletes competed at the international level while 144 athletes competed at the national level. Results showed that athletes who competed at the international level scored significantly higher on *reflection* while individual athletes score significantly higher on *planning* and *effort* compared to team sport athletes (Jonker et al., 2010).

The importance of self-regulatory skills for the development of sports expertise are highlighted in research and it is suggested that young athletes can develop self-regulation skills through youth sports (Coughlan et al., 2014; Jonker, Elferink-Gemser, Tromp, Baker, & Visscher, 2015). Although self-regulatory skills can be developed earlier, typically these skills are developed between 12-16 years of age and it's argued that four contextual factors promote the development of self-regulation: 1) the complexity of the task, 2) the control over the task and challenge, 3) the number of opportunities to evaluate own actions and 4) the number of opportunities to collaborate with others (Perry, 1998). To promote the development of self-regulatory skills, coaches have to create training environments where all four contextual requirements are fulfilled. Next to these contextual factors, it is suggested that an autonomy-supportive coaching style is likely to stimulate the development of necessary self-regulatory skills (Jonker et al., 2015)

A limitation of the Jonker et al. (2010), Toering et al. (2009) and Toering et al. (2012) studies is that self-regulation is measured with the use of a self-report questionnaire which may be influenced by athletes giving socially desirable answers. Secondly, researchers question the ability of people to accurately report their own cognitions and behaviour. These memory errors could lead to two types of mistakes; forgetting, which leads to under estimation and telescoping, which leads to over estimation (Bradburn, 1983). To tackle the self-report limitation, Toering et al. (2011) determined the ability to measure self-regulation through training observations. Firstly, expert coaches were asked to determine specific behaviour items that they thought was associated with the six self-regulation subscales. This resulted in a list of 16 visible behavioural items which were linked to one or more of the six self-regulation subscales. Practice behaviour of 13 youth male soccer players was then coded for the 16 behavioural items and correlated with the self-reported self-regulation scale of Toering, Elferink-Gemser, Jonker, van Heuvelen and Visscher (2012). Results demonstrated that only 9 of the behavioural items were significantly correlated to any of six-subscales and only 5 items were correlated to the overall self-regulation score (Toering et al., 2011). So selecting players with great self-regulatory skills from practice observation is very difficult using the behavioural items proposed by the expert coaches. It was also suggested that some of the players' behaviour could be extrinsically driven as the players from this cohort were playing at the highest youth level and aware of team selections. Toering et al. (2011) highlighted that future research should focus on developing an observation tool to measure self-regulation based on interviews with more coaches as well as players and the use of the observational tool should be examined at different playing levels.

Although the use of self-report questionnaires to measure self-regulation is questioned, it is clear that self-regulatory skills are of influence on playing level in team-sports as well as individual sports. Players with superior self-regulatory skill are likely to plan, structure and monitor their own training and performance more which lead to greater skill improvement per training (Coughlan et al., 2014). It is therefore argued that self-regulated athletes will benefit more from a systematic training program, which is suggested to be one of the main questions during talent identification (Williams & Reilly, 2000). Thus, to get the most improvement in performance level from a talent development program, selectors should identify players with self-regulatory skills.

2.5.6 Developmental sport history

From the previous sections, it is clear that athletes who perform at the highest international level of competition are characterised by a combination of great physical capacities, technical sport-specific technical skills, perceptual-cognitive skills and motivational and self-regulatory skills. All expert athletes had to develop their skills through hours of practice, however, the specifics of this developmental process of expert performers has been the focus of debate for many years. To gain understanding about the developmental of sports expertise, the developmental sporting history of expert athletes has been analysed to determine underlying developmental processes. As mentioned in more detail in the talent development models section, Bloom (1985) interviewed expert tennis and swimmers about their developmental process and proposed the three stage model. A similar approach was adopted by Ericsson et al. (1993) and Côté (1999) which resulted in the development of the deliberate practice theory and the development of the developmental model of sport participation, respectively. Besides using semi-structured interviews, retrospective recall questionnaires were used to determine the influence of different training activities on the development of sporting expertise (Ford et al., 2009; Helsen et al., 1998; Ward et al., 2007). With the use of a retrospective recall questionnaire, an alternative developmental approach was suggested by Ford et al. (2009): the early engagement hypothesis. The primarily focus in this developmental approach is on the accumulation of sport-specific training hours. Although information from retrospective recall interviews and questionnaires has been shown to be successful in the development of talent development models, it lacks detailed information on the microstructure of training, which has been shown to be of influence on skill development (Williams & Hodges, 2005). Several advantages and disadvantages have been raised in the use of the retrospective capture of the developmental sporting history of expert athletes. These are listed by Williams and Ericsson (2005) below:

- Provides a description of the general structure of practice activities leading to expert performance
- Overemphasis on macro rather than micro structure of practice
- Limited attempt to identify specific practice activities (and strategies) that contribute to the development of skills
- Absence of control groups
- Potential concerns with validity of retrospective estimates of practice hours

Despite some of the limitations of the use of retrospective training history, it is argued that this information can provide a better understanding of the development of sport expertise.

Early research in the developmental sporting history of expert athletes favoured the idea of early specialisation; however, more recent work demonstrates the benefits of sampling multiple sports for the development of sport expertise in sports such as netball, basketball and field hockey (Baker, Côté and Abernethy, 2003). Supportive findings for the benefits of sampling multiple sports were provided by Australian footballers who reported that expert decision-makers had accumulated more hours in invasion activities in other sports than Australian Football compared to non-experts, suggesting that there is a positive transfer of decision-making skills across sports (Berry et al., 2008). It was reported that the type of the other activities, shared commonalities with their main sport and could therefore explain the benefits for the development of sport expertise in their main sport (Baker et al., 2003; Berry et al., 2008). For example, expert decision-makers in Australian football gained from playing basketball as both sports are played in a confined space where players developed necessary decision-making and spatial awareness skills (Berry et al., (2008) while expert netball, basketball and field hockey players reported to have engaged in cricket and softball which may have contributed to the development of hand-eye coordination (Baker et al., 2003). The transfer of learning between different sports supports the idea of an early diversification development for the attainment of sport expertise (Côté, 1999).

While retrospective training data of expert athletes might provide understanding on the development of sports expertise; it's not able to provide understanding on the progression through different development stages. Therefore, the influence of key experiences and milestones is investigated to determine the effect of age of specialisation on sport expertise (Bruce, Farrow, & Raynor, 2013; Coutinho et al., 2015; Ford et al., 2012; Gullich, 2014; Gullich & Emrich, 2014). Performance milestones for expert and developmental netball players revealed that expert players began specialising in netball later than their developmental peers (Bruce et al., 2013). Supportive findings for the benefits of a late specialisation developmental process are reported for sports such as field hockey (Gullich, 2014), volleyball (Coutinho et al., 2015) and various game sports (Gullich & Emrich, 2014). Interestingly, no differences were found between expert or non-expert players for the age when players started participating in their main sport (Bruce et al., 2013; Coutinho et al., 2015; Gullich, 2014; Gullich and Emrich, 2014). However, Ford et al. (2012) reported that professional youth soccer players were involved significantly earlier in soccer practice compared to nonprofessional players. A possible explanation for this difference is the depth of competition as there are significantly more active soccer participants compared to netball, field hockey and volleyball which makes it harder to reach the expert level in soccer (Baker & Horton, 2004). Secondly, it could be argued that a certain amount of training in each sport will lead to similar skill improvement; however, due to the depth of competition, the relative improvement compared to peers is less significant in popular sports such as soccer and basketball compared to netball and field hockey. Therefore, athletes have to invest in more training hours to reach the expert level in their sport which influences the developmental pathway of these athletes.

It can be concluded that the information on the developmental sporting history of expert athletes has influenced the development of different talent development models. Furthermore, retrospective recall data on training history is able to provide an understanding about the benefits of early specialisation or early diversification on the development of expertise in different sports. More so, developmental training history can provide an understanding about the influence of different training activities and training volume on the development of sports expertise.

2.6 The relative age effect

In most school systems, children are placed into age groups to avoid large age differences between children in groups. In these age groups, the maximal difference between children is 364 days and this is associated with differences in cognitive development and related to academic problems for the relatively younger children (Bell & Daniels, 1990). Evidence from growth charts of typically developing children show that extensive differences in height and weight can occur when a child from the 5^{th} percentile of his age competes against a child 12 months older child from the 95^{th} percentile (Tanner & Whitehouse, 1976). This phenomenon that late born children are negatively influenced because of their birth-date is called the relative age effect (RAE). Similar age grouping principles are applied in sport systems to decrease age differences, however, it is clear from several studies that the RAE is also apparent in sports such as Australian football (Cripps, Hopper, Joyce, & Veale, 2015), alpine skiing (Baker, Janning, Wong, Cobley, & Schorer, 2014), baseball (Thompson, Barnsley, & Stebelsky, 1991), basketball (Arrieta, Torres-Unda, Gil, & Irazusta, 2016), cross-country skiing

(Baker et al., 2014), ice-hockey (Barnsley & Thompson, 1988), rugby league (Till et al., 2010), ski jumping (Baker et al., 2014) and soccer (Barnsley, Thompson, & Legault, 1992; Cobley, Schorer, & Baker, 2008; Helsen, van Winckel, & Williams, 2005). Early born players are over-represented in selection teams compared to their late born peers, likely as a result of cognitive, physical and emotional differences between the youngest and oldest children (Malina, 1994; Musch & Grondin, 2001). The power of the RAE is demonstrated by Helsen, Starkes and van Winckel (2000) who showed that when the cut-off date in youth soccer shifted from August 1 to January 1, the RAE shifted accordingly.

The RAE seems to create an unequal advantage for youth players born in the first months after the cut-off date which is not ultimately related to sporting success at an adult age, as it is demonstrated that the birthdates of players who received a most valuable player award in Australian football, baseball, ice-hockey and soccer were equally distributed (Ford & Williams, 2011). As a consequence, several solutions for the RAE are proposed. Firstly, Musch and Grondin (2001) advocated the use of biological age as a selection criterion instead of chronological age. This would create a more equal competition as players would have similar physical capacities. Secondly, it was proposed that the creation of more variation in the cut-off date would create a more equal competition. For example, if the cut-off date was shifted from a 12 or 24 month (annual) cycle to a 9 or 21 month cycle, is has been suspected that each athlete would have a relative age advantage during adolescence which would decrease the relative age effect in sports (Helsen et al., 2000; Helsen et al., 2012; Musch & Grondin, 2001). Thirdly, Helsen et al. (2000) argued that the RAE would decrease if selection teams were required to have an average age. For example, if the age range is 12-14 year, the average age of the players should be 13 years.

To explain the influence of the RAE on the development of sports expertise, a theoretical framework was proposed by Wattie, Schorer and Baker (2015). A constraints-based developmental systems model described the breadth and the complexity of the influence of relative age effect in sport (see Figure 2.8). This model is based on Newell's model of constraints (1986) where three types of constraints interact with each other to guide control and coordination. That is, the organismic, task and environmental constraints. According to Wattie et al. (2015) each of the three types of constraints has influence on the presence of a RAE. Obviously, the birth date of an athlete (an organismic constraint) influences the relative age of an athlete, however, this advantage or disadvantage only occurs with an age-grouping policy (an environmental constraint). The type of sport and level of competition (task constraints) have been shown to be of influence on the existence of a RAE (Musch & Grondin, 2001). From these examples it is clear that the three constraints influence the presence of the RAE and that the RAE influence the three types of constraints. Furthermore, the three types of constraints and the RAE influences the development of sports expertise. Therefore, athletes born in the first quartile don't always become expert athletes and athletes born in the fourth quartile can become expert athletes based on the unique interaction of constraints and the RAE.

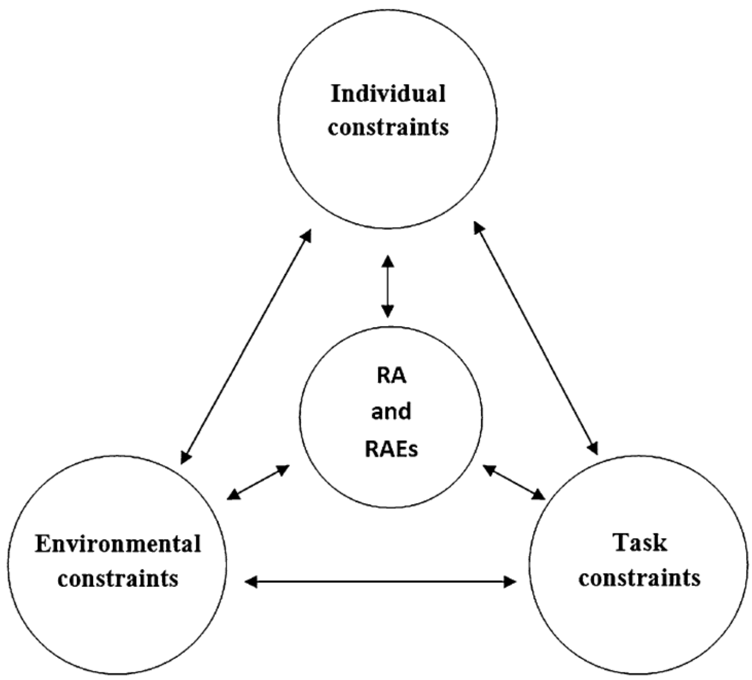

Figure 2.8. The constraints-based model for relative age effect in sports (reproduced from Wattie et al., 2015).

2.7 The effect of maturational status

Further to the differences in chronological age, differences in maturational status are apparent between adolescents and these differences are related to the timing and ratio of growth with the most common indicator of maturational status being Peak Height Velocity (PHV) (Malina, Bouchard, & Bar-Or, 2004). PHV can be measured in a non-invasive way with the use of height, weight, leg length, sitting height and age (Mirwald, Baxter-Jones, Bailey, & Beunen, 2001). With the use of a formula, the maturity offset of the average PHV for males or females can be calculated. Early maturation is defined as preceding the average PHV by 1 year, average maturation is defined as having your PHV ±1 year from average PHV and late maturation is defined as having your PHV >1 year after the average PHV (Sherar, Mirwald, Baxter-Jones, & Thoms, 2005). For males, average PHV is at the age of 14 years old and for females the average PHV is at the age of 12 years old. The combination of differences in chronological age with the differences in maturational status can lead to biological differences of two to three years within an age group (Malina et al., 2004). Biological age has been shown to be of influence on a range of physical and physiological factors important to sports performance such as endurance, anaerobic power, agility and strength (Pearson, Naughton & Torode, 2006). The relationship between maturational status and performance testing in basketball revealed that early maturers outperformed their later maturing peers on grip strength and a medicine ball throw (Coelho E Silva, Figuierdo, Moreira Carvalho, & Malina, 2008). These findings are consistent with other research in soccer where maturational status was the main contributor to the performance on the multistage shuttle run test (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004). Instead of evaluating the influence of maturational status on performance testing, a study into Australian football revealed that maturational status also affected in-game performance (Gastin, Bennet, & Cook, 2013). With the use of GPS, running performance of youth players was measured and results showed that early maturing players covered more metres per minute, more metres in high intensity running and reported a higher peak speed (Gastin et al., 2013). Interestingly from a group of 55 talented youth soccer players, a significantly bigger proportion of late maturing players reached the professional level compared to the early maturing players (Ostojic et al., 2014).

The results from the research reviewed provide evidence that the RAE and the maturational status of players influence the likelihood of a player as being identified as talented, and in turn their selection prospects. Therefore, these factors should be considered by policy makers and selectors during talent identification to prevent mis-identification based on seemingly short-term advantages.

2.8 The constraints-led approach

The positive relationship between training and the development of sports expertise is clear from several studies into the developmental sport history of expert athletes (Côté, 1999; Ericsson et al., 1993; Ford et al., 2009). Interestingly though, the focus is on type and volume of training and not much detail about the content and design of practice is provided. A motor learning paradigm that provides more detailed information about practice design is the constraints-led approach (Davids, 2010; Davids, Button, & Bennet, 2008; Renshaw, Chow, Davids, & Hammond, 2010). If we take one more step back, the constraints-led approach is derived from the dynamical systems theory, a theoretical perspective that explains motor control and motor learning. This theory is based on the principle that the human body (a movement system) is a highly interactive system of co-dependent sub-systems that are again built of a large number of interactive components. It is suggested that learning is a shift in balance between the dynamics of the human movement system and external information which occurs through self-organisation (Kelso et al., 1995). Changes in movement abilities are a function of the movement system itself and are not prescribed by a higher authority. Learning a skill implies that the movement system has become a stable state (Kelso et al, 1995).

Reaching a stable state often requires transition between three different stages: coordination, control and skill. Coordination is the process whereby components of the human movement system are synchronized to each other during a goal-directed activity (Turvey, 1990). Control is the process whereby the actor is able to alter parameters such as force, joint angles and direction, to reach a specific goal. Skill is the process whereby the movement system is able to create goal-directed behaviour in the most optimal way for that situation. Bernstein (1967) argued that the motor control and coordination of movement is about scaling down the degrees of freedom of a movement system into a controllable system that can interact with the environment According to the constraints-led approach, the interaction between three key constraints are of influence on the acquisition of movement and coordination of actions: organism, environmental and task constraints (Newell, 1986).

1. Organismic constraints refer to characteristics of an individual such as physical, cognitive and motivational characteristics. These unique organismic constraints can be used to solve

movement problems as well as limit an individual in his movements. Therefore, each individual has his own action capabilities that will influence the interaction with the two other constraints. For example, the ability to accelerate will dictate if a soccer player will try to intercept a pass from his opponent.

2. Environmental constraints refer to characteristics of the surrounds such as lighting and weather as well as more social related factors such as the presence of a crowd. For example, sport policy makers influence age-grouping which might affect the existence of the RAE.
3. Task constraints refer to the characteristics of a performance context such as the goal of an activity, the rules of a sport, equipment and playing surface. These constraints are of major influence on the available perceptual information for an individual to guide his movement and therefore, coaches and physical educators are predominantly manipulating task constraints to create appropriate learning environments. For example, by lowering the player numbers, a field hockey player has less possible teammates to pass the ball to.

The interaction between the three constraints dictates the available array of energy flows, which can be used by a performer as informational sources and guide decision-making and movement solutions of goal-directed behaviour (Gibson, 1979). These energy flows provide opportunities for an individual to interact and are called *affordances*. This interaction between affordances and movement dictate the perception and action coupling and as such, the perceptual information that guides the behaviour of an individual and their actions create new perceptual information to further guide behaviour (see Figure 2.9).

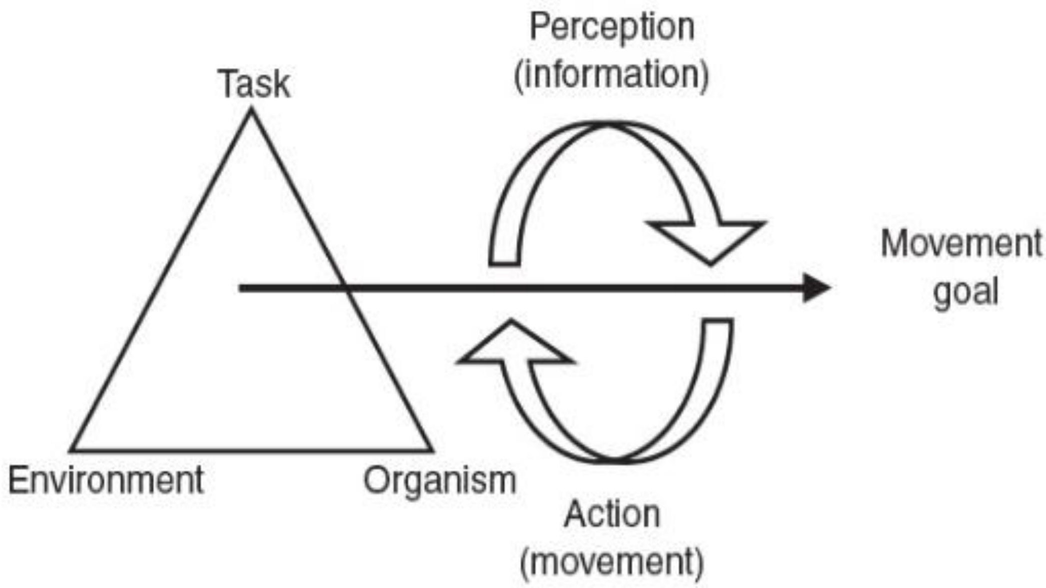

Figure 2.9. Graphical representation of the interaction between the three key constraints to guide goal-directed behaviour and the coupling between perception and action.

2.8.1 The constraints-led approach as framework for skill acquisition

For skill acquisition, this implies that athletes have to pick-up information from the environment to guide their goal-directed behaviour and create information-movement couplings. In this process, athletes first have to get better at detecting the specific information from the available information to select the critical information that guides behaviour. Secondly, athletes have to calibrate their actions to critical information and create an information-movement coupling. Through this process, athletes get attuned to relevant information (Jacobs & Michaels, 2002). This process of learning is further divided into three stages of learning: a freezing, freeing and exploiting phase (Savelsbergh & van der Kamp, 2000). During the freezing phase athletes get attuned to information to create information-movement couplings and practice will lead to more robust couplings. In the second stage of learning, the freeing of information-movement couplings occurs. When athletes are practising skill under different constraints, a bigger repertoire of possible couplings are created and due to this bigger repertoire athletes are able to use a different information-movement coupling to solve the movement problem. In the last stage of learning, athletes are able to exploit new movement solutions with the use of different information-movement couplings. So expert athletes are able to use information from one coupling and link it to an action from a different coupling. Therefore the athlete is able to use the same information for multiple actions (Savelsbergh & van der Kamp, 2000).

The importance of the interaction between the environment and the organism lies in the coupling between perception and action and therefore it is critical that the correct information is available for athletes to become attuned for the guidance of behaviour. To help early learners pick up the specific information from the environment to guide their behaviour, coaches and physical educators are able to create simplified versions of tasks (Davids, 2010). During the process of task simplification it is of importance to create training environments where the link between information and movement is maintained so learners can create information-movement couplings that are representative of the performance context (Pinder, Davids, Renshaw, & Araújo, 2011). For example, by lowering the number of players in a game of field hockey, the number of potential connections (teammates) and opponents is decreased which is suggested to simplify the task. It has to be emphasised that task simplification is not task decomposition, where a task is divided into separate actions and trained accordingly. Task decomposition will lead to incorrect information-movement couplings and as such, a different skill is practised (Renshaw, Oldham, Davids, & Golds, 2007). For example, ball-machines are often used to improve goalkeeping skills in field hockey; however, the lack of available kinematic information from a shooter will lead to the creation of incorrect information-movement couplings.

As mentioned before, in order to facilitate decision-making and skill acquisition, practice environments have to be representative of the performance context to create appropriate information-movement couplings (Pinder et al., 2011). A method used by coaches and physical educators to create appropriate and simplified training environment is to scale equipment or field dimensions (task constraints) to increase the opportunities to perform skills in a proficient way. Buszard, Farrow, Reid and Masters (2014) demonstrated that young children increased their hitting performance and hitting technique in tennis when provided with a smaller racquet and a modified ball (lighter and low-compressed ball). Modified racquets and tennis balls are examples of modified task constraints and will therefore influence the interaction between the three constraints and in this case, promote skill acquisition in tennis. In sports such as basketball, field hockey and soccer, appropriate training environments are created by using small-sided games (SSG). These SSG can be manipulated in multiple ways, for example, by changing the rules, the field dimensions, number of players and playing time. These manipulations will influence the creation of information-movement couplings as different perceptual information is available. Research into the effect of manipulating task constraints in small-sided games has focused on technical skill demands, physiological demands as well as tactical demands (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012; Frencken, Lemmink, Delleman, & Visscher, 2011; Gabbett, Jenkins, & Abernethy, 2009). It has been demonstrated that increasing the number of players in basketball and soccer led to an increase in the percentage of successful passes and a decrease in the number of passes and dribbles (Dellal et al., 2011; Klusemann, Pyne, Foster, & Drinkwater, 2012). In contrast, increasing the number of players in water polo led to more passes and offensive actions (Lupo et al., 2009) while in Australian football manipulating the numbers of players did not have any effect on the frequency of technical actions (Davies, Young, Farrow, & Bahnert, 2013). These findings demonstrated that manipulating the same task constraint in different sports will lead to a different change in playing behaviour. It is suggested that these differences lie in the interaction between players and the performance context. Different task constraints such as the characteristics of the ball, playing surface (grass or water) and the rules of the game influences the available perceptual information and will therefore lead to different goal-directed behaviour. Similar results can be found for the effect of manipulating the personal playing area (density) on technical playing behaviour when sports such as rugby league, soccer and water polo are compared (Casamichana & Castellano, 2010; Gabbett, Abernethy & Jenkins, 2012; Lupo et al., 2009). It is clear that manipulating task constraints influences the frequency of technical skill actions and it is therefore suggested that this will influence the development of decision-making skills and sport-specific technical skills.

To determine the effect of manipulating task constraints of SSG on the physiological demands, Global Positioning Systems (GPS) has been used to track players' movement (Aughey, 2011). It was demonstrated by Owen, Wong, Paul and Dellal (2013) that the physiological demands of SSG were comparable with those of a full-field game in soccer. The influence of player numbers was examined by Dellal et al. (2011) and Casamichana, Quintana, Castellano and Calleja-Gonzalez (2015) who demonstrated that the physiological demands of soccer increased when the number of players increased. Inconsistent findings were revealed for the influence of manipulating player numbers in Australian football (Davies et al., 2013). Increasing the personal playing area per player in soccer leads to players covering more metres per minute (Casamichana & Castellano, 2010; Castellano, Puente, Echeazarra, Usabiaga, & Casamichana, 2016). Consistent findings for the influence of manipulating density were found in Australian football (Davies et al., 2013) and rugby league (Gabett et al., 2012).

2.8.2 The constraints-led approach as framework for talent development.

According to the DMGT, the talent development process is an interaction between natural abilities of an athlete, intrapersonal catalysts, environmental catalysts and type of learning. A similar dynamic approach to talent development is presented by Rees et al. (2016). In this model, talent development is the result of an interaction between the performer, the environment and training and practice. Both models imply that the unique personal characteristics of an athlete influence the talent development process of an individual and that therefore, no talent development pathway of an athlete is the same. These personal characteristics have to interact with the environment as well as with training and practice characteristics to develop the necessary skills to become an expert performer. From previous sections of this literature review it is clear that athletes possess unique anthropometric, physiological, perceptual-cognitive and self-regulatory skills (examples of organismic constraints) and as such, interact in a unique way with environmental and task constraints (Newell, 1986). Young athletes who are provided with the same learning environment will pick-up different perceptual information to find a movement solution that fits their personal constraints. This constant interaction between the three types of constraints could explain differences in the rate of development of sports expertise between athletes and therefore how much “talent” an athlete possesses. One could argue that the most talented player is the one who is able to interact with the task and environmental constraints in the most efficient way and who is able to achieve a constant level of performance in an ever changing performance context (Davids, Araújo, Vilar, Renshaw, & Pinder, 2013). Due to development of the body itself and the demands of the performance context, an athlete could be considered as a talented athlete at one point in time while his less-talented peer is better able to deal with the changing performance context later on which then makes him the talented athlete. This complex interaction increases the complexity of talent prediction and as Baker, Schorer and Cobley (2012) have argued the predictive value of talent prediction/identification becomes less reliable as the time between the identification and the actual performance increases. Simply put, identifying sporting success for an U21 national team is less reliable when done at the age of 14 years compared to the age of 20 years. The more time between the identification and the actual performance, the more change that the interaction between the three constraints which will alter the performance level of a talented athlete (better or worse). For example, an early matured young sprinter could be identified as a talented athlete, due his physical advantages, however, during later stages of development, when all the athletes have gone through puberty and physical abilities have become more homogenous, other personal characteristics will determine who’s talented.

It can be concluded that coaches and physical educators should be aware of the unique interaction of constraints when manipulating task constraints to promote the acquisition of decision-making and sport-specific technical skills and the improvement of physical capacities. Furthermore, it can be argued that the constraints-led approach could explain the differences in rate of development due to the interaction between organismic, task and environmental constraints. To create performance environments where players are able to development necessary field hockey technical and physical skills, the influence of manipulating task constraints has to be determined. Due to some of the differences in performance context, it can’t be assumed that results of previous studies in other sports will translate to field hockey. Therefore, the effect of manipulating competition structures has to be determined to be able to create appropriate learning environment where young field hockey players can interact with the environment in such way that their development is optimised. Furthermore, is has been shown in several different sports that engagement in game-based activities were beneficial for the development of sporting expertise. Therefore, the effect of manipulating SSG has to be determined to be able to develop guidelines for the creation of appropriate training environments in field hockey

2.9 Conclusion and summary

It is clear that the performance level of field hockey players is influenced by a wide range of performance characteristics and as such, talent selection should account for this. Although research has showed that a one-dimensional testing battery is able to distinguish between performance levels of different athletes, there is general agreement that a multi-dimensional objective approach to talent selection is able to provide a better and more holistic view of the performance level of a field hockey player. The combination and relation between certain performance characteristics is able to provide more critical information about the level of 'talent' an athlete possesses than one-dimensional testing. Therefore, a multi-dimensional objective testing battery can be a useful tool for coaches and selectors. Furthermore, such a testing battery is able to provide information about influential factors such as maturational status and practice history. Coaches and selectors can therefore make more informed decisions on the amount of 'talent' an athlete possesses which increases the predictive value of talent identification.

There is agreement amongst researchers and practitioners that young athletes need to develop necessary field hockey skills through the amassing of an extensive amount of practice hours, however, the type and volume of training that is needed to reach an expert level might be individually dependent. Several personal and environmental factors might influence the ability of a young athlete to cope with certain training environments and as such, influence the developmental pathway of a young athlete. Another factor that influences the developmental process of an athlete is the exposure to appropriate training and competition environments. To improve the performance level of players, training and competition environments should be created where players are able to learn skills that are specific to the performance context. By doing so, players are able to find movement solutions that are specific to their action capabilities and players can develop skills in their own pace.

2.10 Aims of this thesis

This thesis sought to address two aims:

1) To evaluate what performance characteristics distinguish between skill levels at different stages of development (age) by using a multi-dimensional objective approach to performance

testing in field hockey. Addressing this aim will also detail what talent selectors perceive are the important performance characteristics at different stages of hockey development.

2) To gain a more complete understanding of the influence of competition and training environments on the emergence of critical field hockey skills (as identified in the first thesis aim).

In order to achieve the first aim, a cross-sectional design was adopted where field hockey players of different ages and different playing levels (i.e., club or state representative level) were required to perform a holistic field hockey specific testing battery. In order to achieve the second aim, two different experiments were conducted. Firstly, the influence of manipulating the number of players and personal playing area on sport-specific technical skill, physical and decision-making demands in competition environments was determined. Secondly, a series of small-sided games (SSG) were developed and evaluated to determine the influence of task manipulations on physical and technical skills demands of SSG.

Chapter Three

Examining the influence of multiple performance characteristics on selection into a representative team in field hockey

Abstract

The aim of this study was to determine what kind of performance characteristics distinguish between different skill levels at different development stages in field hockey using a multi-dimensional testing battery. A total of 100 players identified as 'talented' (51.0% girls) and 105 recreational level players (41.0% girls) divided over three age groups (U13/U15/U18) performed anthropometric, physical capacity, sport-specific technical skill and decision-making tests and completed self-regulation and sport history questionnaires. Gender specific multivariate analysis with playing level and age group as factors and age as a covariate were performed. Results revealed that experienced selectors and coaches select players for representative teams predominantly based on their dribbling skills, passing/hitting skills and speed and endurance. Furthermore, it is clear that selection for such a representative team is strongly influenced by maturational status and accumulated field hockey specific training hours. Interestingly, no differences were found between the self-regulatory skills of state and club level players for either gender. This study highlighted the performance characteristics deemed to be important by selectors and coaches and emphasised the need to consider the strong influence of maturational status and practice history when selecting 'talented' players as these factors don't translate to future sporting success.

3.1 Introduction

The search for and quantification of 'talent' in athlete populations has become a significant focus for both researchers and national sporting organisations. This is the case for many different sports and certainly for field hockey in Australia, where selection for regional and state/territory teams begins at the age of 12 years. Selection of talent is typically done by experienced selectors and coaches who select players they feel have the potential to become an elite athlete and consequently, the skills of selected players represent what coaches consider as important. Researchers have also tried to determine what kind of performance characteristics in field hockey are most important with the use of objective testing batteries (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Keogh, Weber, & Dalton, 2003; Nieuwenhuis, Spamer, & van Rossum, 2002). By doing so, trainers and physical educators are able to design appropriate training environments where players can develop skills that are deemed to be important to play at a high level of competition.

It has been argued that these testing batteries predominantly focused on an overly restrictive range of capacities or skills at the expense of many other qualities that obviously contribute to sports performance and therefore misinterpreting the complexity of expert sports performance (Burgess & Naughton, 2010; Lidor, Côté, & Hackfort, 2009; Phillips, Davids, Renshaw, & Portus, 2010). This issue has been highlighted in the extant literature where is it has been argued that: (a) physical skills are only one aspect of the many factors that contribute to expert performance; (b) there is a lack of consideration of the perceptual-cognitive components of skills such as decision-making and anticipation (see Farrow, 2012 for an exception); and (c) there is a need for a multi-dimensional approach to the identification of discriminating performance characteristics between performance levels (Burgess & Naughton, 2010; Abbott, Button, Pepping, & Collins, 2005).

Evidence of the effective use of multi-dimensional approaches to identify discriminating performance characteristics are found in sports such as field hockey, rugby league and soccer (Elferink-Gemser et al., 2004; Till et al., 2015; Vaeyens et al., 2006). These studies demonstrated that selected players outperformed their non-selected peers on anthropometric, physical capacity and sport specific technical skills. Furthermore, research investigating the discriminatory ability of multi-, and mono-disciplinary testing batteries in Australian football showed that a multi-disciplinary testing battery classified a higher percentage of players correctly compared to a mono-disciplinary testing battery (Woods, Raynor, Bruce, McDonald, & Robertson, 2016). Despite the multi-dimensional approach, there is a lack of perceptual-cognitive measurements in these studies despite these skills having been shown to discriminate between playing levels (Savelsbergh, Haans, Kooijman, & van Kampen, 2010; Ward & Williams, 2003). Acknowledging the above issues, it is established that a well-constructed, objective multi-dimensional test battery can be a very useful tool to supplement the perceptions of coaches/selectors and allow coaches to empirically monitor their athletes development and if used longitudinally predict a player's potential.

The potential of an athlete is also related to his/her ability to learn and this is influenced by the self-regulatory skills of an athlete (Jonker, Elferink-Gemser, & Visscher, 2010). Studies of self-regulation show that high performing players outperform their lower performing peers on self-regulatory skills (Jonker et al., 2010; Toering, Elferink-Gemser, Jordet, & Visscher, 2009). In these studies, self-regulation is described as the extent to which high performing athletes are metacognitively, motivationally and behaviourally proactive in their own learning process (Zimmerman, 1986). A second aspect that influences an athlete's learning curve is the amount and quality of practice a performer completes. Most influentially detailed by Ericsson, Krampe and Tesch-Römer (1993) it is argued that early engagement and extensive amounts of deliberate practice is required to attain an expert level of performance in domains such as music and sports. Studies in field hockey and soccer have shown consistent findings, supporting the idea of early specialisation as a critical for sporting success (Helsen, Starkes, & Hodges, 1998). However, more recent studies suggest that early specialisation may be detrimental and argue that early diversification and deliberate play is as important to sporting success, particularly in sports where peak performance occurs after maturation (Baker, Côté, & Abernethy, 2003; Côté, Lidor, & Hackfort, 2009).

In summary, multiple factors influence the performance level of an athlete and his/her chance to be considered as a 'talented' player by selectors and coaches. The aim of this study was to determine what kind of performance characteristics distinguish between skill levels at different developmental stages in field hockey using a multi-dimensional testing battery. With the use of a cross-sectional design the differences between club level and representative state level players of different ages and gender was determined for anthropometric, physical capacity, sport-specific technical skill, decision-making, self-regulation and sport history characteristics. Based on previous research (Elferink-Gemser et al., 2004; Toering et al., 2009; Woods et al., 2016) it was predicted that state level players would possess a greater physical capacity, better sport-specific technical skills, better decision-making skills and more self-regulatory skills and report more sport specific training hours as well as more informal play.

3.2 Methods

3.2.1 Participants

A total of 205 hockey players (94 female and 111 male) volunteered to participate in this study after ethical approval was granted from the university and parental consent was obtained. A total of 100 players had been identified as a talented hockey player and invited to participate in a talent development squad of the Hockey federation after having represented their state in a national championship. The other 105 players played hockey at a recreational level for their respective club. The number of players per age group and anthropometric characteristics are listed in Table 3.1.

3.2.2 Experimental design

Participants were divided into three age groups (under-13, under-15 and under-18) based on their age at the start of the season. All players were tested before or during the 2015 Australian hockey season (January 2015-June 2015) and assessed for the following characteristics: anthropometric, physical capacity, sport-specific technical skill, decision-making, self-regulation and sport history (e.g., practice hours, sporting experiences). A cross-sectional design was adopted to determine the relationship between the six different performance characteristics and playing level. Some of the tests chosen in the multi-dimensional testing battery were part of a testing battery often used by Hockey Australia to test the fitness of their players (grip strength, agility test, sprint tests and multi-shuttle run test). Other tests were chosen for their practicality or proven reliability and validity by other researchers. The passing, hitting and decision-making tests were specially developed for this testing battery.

Table 3.1. Number of participants and mean (±SD) of age (years), height in centimetres (cm), weight in kilograms (Kg), body fat percentage (%), and age at Peak Height Velocity (PHV) of state and club level players per age group and gender and the MANCOVA comparison between playing levels.

	U13		U15		U18		MANCOVA	
	State	Club	State	Club	State	Club	F	*p*
Female								
n	18	21	24	16	9	6		
Age (years)	12.6 (0.2)	12.1 (0.2)	14.0 (0.2)	13.9 (0.2)	16.3 (0.3)	16.3 (0.3)	1.75	0.189
Height (cm)	156.0 (7.8)	154.9 (7.1)	162.0 (6.0)	162.6 (5.5)	167.7 (3.7)	165.3 (7.5)	>0.01	0.948
Weight (Kg)	46.4 (8.8)	45.7 (6.7)	54.5 (6.8)	56.7 (9.2)	62.8 (4.2)	60.8 (8.8)	0.20	0.660
Body fat (%)	22.8 (5.1)	22.7 (3.9)	23.7 (5.7)	26.3 (5.7)	25.5 (4.5)	27.5 (4.9)	1.57	0.214
Age at PHV	12.4 (0.4)	13.0 (0.8)	12.6 (0.5)	13.1 (1.1)	13.2 (0.4)	14.7 (2.1)	20.50	>0.001
Male								
n	24	26	19	27	6	9		
Age (years)	12.5 (0.2)	11.7 (0.1)	14.0 (0.2)	14.1 (0.1)	16.2 (0.3)	15.9 (0.3)	4.70	0.032
Height (cm)	153.1 (6.3)	149.5 (7.9)	165.0 (8.3)	167.2 (9.0)	178.0 (5.7)	175.7 (7.9)	0.02	0.884
Weight (Kg)	42.0 (6.5)	41.4 (7.1)	52.5 (8.5)	55.0 (9.5)	72.4 (10.6)	65.0 (9.2)	0.07	0.798
Body fat (%)	14.2 (3.9)	17.7 (6.2)	13.4 (2.9)	13.4 (3.4)	15.1 (4.5)	12.8 (5.5)	0.04	0.845
Age at PHV	13.9 (0.4)	14.3 (0.5)	13.9 (1.3)	14.1 (0.8)	13.9 (0.6)	14.5 (0.9)	6.78	0.010

3.2.3 Test procedures

3.2.3.1 Anthropometric measurements

Body composition was measured using seven variables: height (cm), weight (kg), body fat percentage (%), sitting height (cm), leg length (cm), the age at Peak Height Velocity (PHV) (years) and the birth distribution of the players. Percentage of body fat was measured using a bioelectrical impedance (BIA) scale (BC-533 scale, Tanita, Arlington Heights, Illinois, USA). BIA has been shown to be a reliable and quick measurement of the percentage of body fat in healthy subjects and athletes (Lukaski, Bolonchuk, Hall, & Siders, 1986; Ostojic, 2006). Sitting height was determined by measuring the height of a participant sitting on a chair and then subtracting the height of the chair. Leg length was calculated by subtracting the sitting height of the standing height. Age at PHV was calculated as described by Mirwald, Baxter-Jones, Bailey, and Beunen (2001): Maturity offset for males = -9.236 + 0.0002708 * (Leg length and sitting height interaction) – 0.001663* (age and leg length interaction) + 0.007216 * (age and sitting height interaction) + 0.02292 * (weight by height ratio). Maturity offset for females = -9.376 + 0.0001882 * (leg length and sitting height interaction) + 0.0022 * (age and leg length interaction) + 0.005841 * (age and sitting height interaction) – 0.002658 * (age and weight interaction) + 0.07693 * (weight by height ratio).

3.2.3.2 Physical capacity measurements

Players were asked to perform six different tests to determine their physical capacity. These included: flexibility, grip strength, leg power, 5- and 20-metre sprint tests, 5-0-5 agility test and a multistage shuttle run test.

Flexibility of the lower back and hamstrings was measured using the sit and reach test (Wells & Dillon, 1952). Players were asked to place the sole of their feet flat against the box while keeping their leg stretched out and reach forward along the measuring line as far as possible and hold that position for 2 seconds. Test-retest reliability (ICC) of the sit and reach test is 0.93; suggesting that this is a reliable test (Wells & Dillon, 1952).

Grip strength was measured in kilograms by using a hand grip dynamometer (S Dynamometer, TTM, Tokyo, 100 Kg). Participants were asked to hold the grip dynamometer in their dominant hand and raise their arm above their head. They were then asked to bring their arm to their trunk while squeezing the grip dynamometer as hard as they could. Test-retest reliability (ICC) of the of the hand grip dynamometer is >0.80; suggesting that this is a reliable test (Roberts et al., 2011).

Leg power was measured using the calculation: *Peak Power (W) = (60.7 * Jump Height (cm)) + (45.3 * Body Mass (Kg)) – 2.05* (Sayers, Harackiewicz, Harman, Frykman, & Rosenstein, 1999). Participants were first asked to stand side-on to a Yardstick (Swift Performance, Wacol, Australia), keeping their heels on the floor and reaching out as high as possible. This was recorded as their standing height. Participants were then asked to use a countermovement jump with arm swing to jump as high as possible with no preliminary steps were allowed. The difference between the countermovement jump height and the standing height was then used in the calculation of Jump Height. Test-retest reliability (ICC) of the of the countermovement jump is 0.98; suggesting that this is a reliable test (Markovic, Dizdar, Jukic, & Cardinale, 2004).

Participants speed was recorded through the use of a 20m sprint test where the 5m and 20m times were recorded by the use of timing gates (Smart Speed Pro, Fusion Sports, Coopers Plains, Australia). Participants started with their front foot toe 20cm behind the start line in a 'ready' position and were instructed to start in their own time once the timing system was ready and to sprint as fast as possible. Split time (5m) and final sprint time (20m) were recorded to the nearest 0.01 second.

The 5-0-5 agility test was used as a measurement of the participants' ability to change direction at speed (Woolford, Polgaze, Rowsell, & Spencer, 2013) (see Figure 3.1). Participants were asked to use a similar starting position as during the straight sprint and agility time was recorded with the use of timing gates (Smart Speed Pro, Fusion Sports, Coopers Plains, Australia) to the nearest 0.01 second.

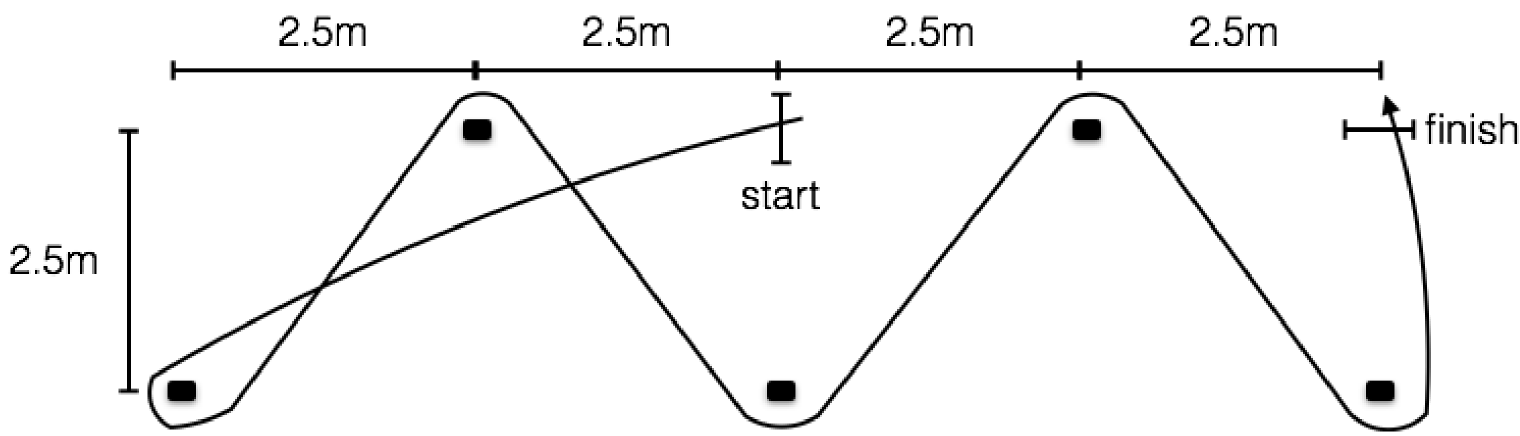

Figure 3.1. Graphical representation of the 5-0-5 agility test (adopted from Woolford et al., 2013).

The multi-stage shuttle run test was used as a measurement of aerobic fitness (Ramsbottom, Brewer, & Williams, 1988). Two lines were clearly marked with a distance of 20m between the lines. Participants were asked to start behind the first line and try to make the opposite line before the beep. Each minute, the time between beeps decreased and hence the subsequent running speed required increased. Participants were asked to keep running until exhaustion. Participants were stopped when they fell short of the 20m line twice in succession. Their score was then used to calculate their VO_2max using the following calculation: $VO_2max = 14.4 + 3.48 * (\text{shuttle level})$ (Ramsbottom et al., 1988). Test-retest reliability (ICC) of the multi-stage shuttle run test is 0.93; suggesting that this is a reliable test (Liu, Plowman, & Looney, 1992).

3.2.3.3 Sport-specific technical skill measurements

To measure the technical skills of the participants, they were asked to perform three different field hockey specific tests: A passing and hitting for accuracy test and a dribble test under single- and dual-task conditions.

As a measure of passing and hitting accuracy, participants were asked to start at the cross and receive the ball from a ball-dispenser before pushing/hitting the ball as accurately and fast as possible into one of the accuracy score boards (see Figure 3.2a). Participants had six balls delivered to them from the ball dispenser in a continuous fashion and had to hit the targets in a set order (left, middle, right repeated twice). A passing time (s) and accuracy score was recorded based on the scoring zones on the rebound board (see Figure 3.2b). Consistent with game conditions, the passing test target was located 10m from the participant and 20m in the hitting test. Participants were asked to perform two trials and the average score was taken.

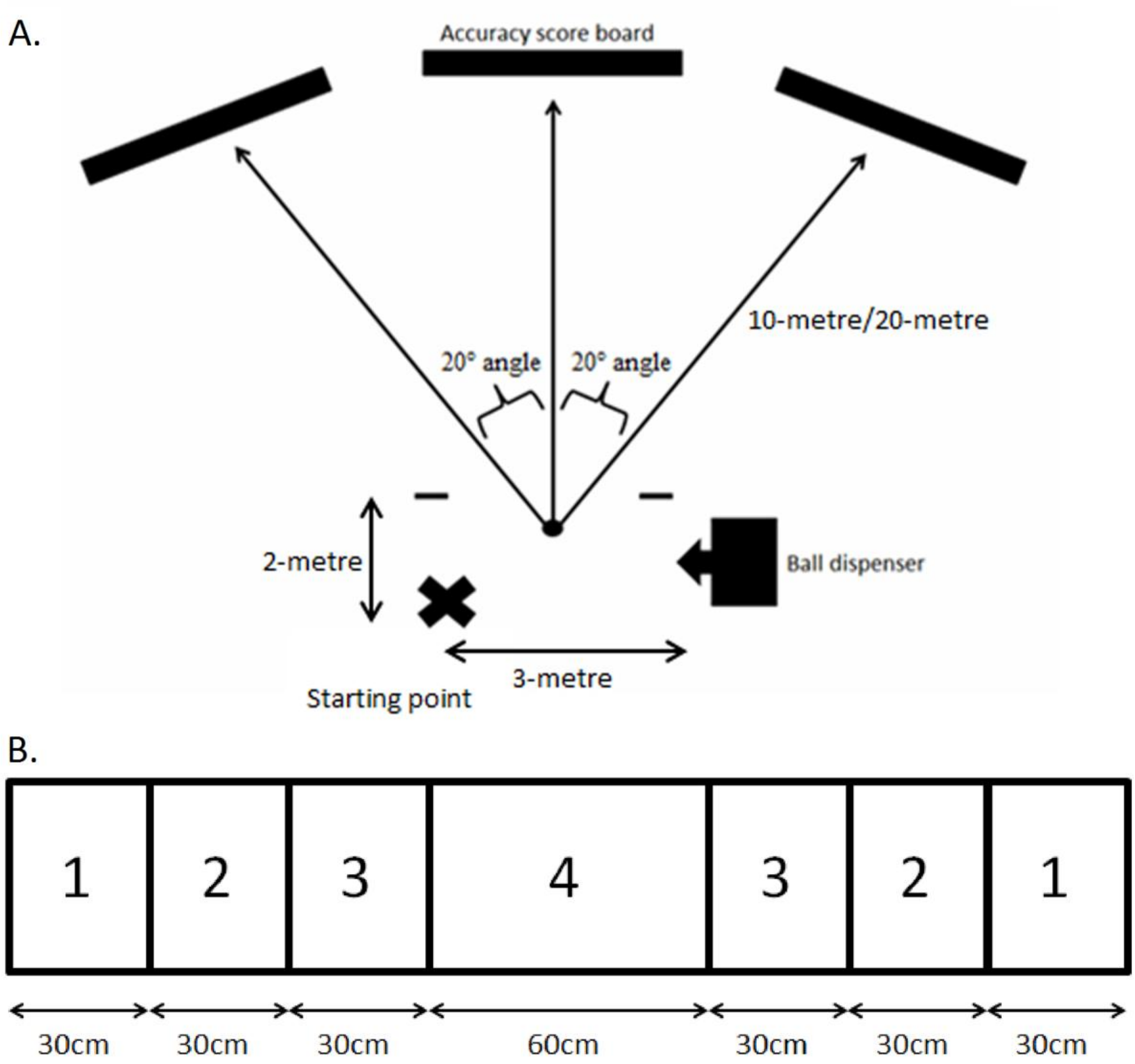

Figure 3.2. a) Graphical representation of the passing and hitting for accuracy test. b) Graphical representation of the accuracy score board.

To test the participants’ ability to maintain control of the ball while running and turning, a previously validated slalom dribble test was used (Lemmink, Elferink-Gemser, & Visscher, 2004). Participants were asked to dribble the ball with their own hockey stick as fast as possible from the start line towards the finish line whilst performing 12 changes of directions of 120° (see Figure 3.3).

Their dribbling time was recorded with the use of timing gates (Smart Speed Pro, Fusion Sports, Coopers Plains, Australia) to the nearest 0.01 second. In addition to the slalom dribble test of Lemmink et al. (2004), a dual-task condition was introduced. Participants were asked to name the colour presented on a laptop (15 inch screen), located 3 metres left of the last timing gate (see Figure 3.3) while completing the slalom dribble test as fast as possible. A letter was presented every 3 seconds and a score was recorded for the amount of correctly named colours. To measure the ability of dual-tasking, the difference between the single- and dual-task dribble test was calculated (dribble delta). Participants were asked to perform two trials in both conditions and the fastest time was taken. Test-retest reliability (ICC) of the single-task dribble test is 0.78; suggesting that this is a reliable test (Lemmink et al., 2004).

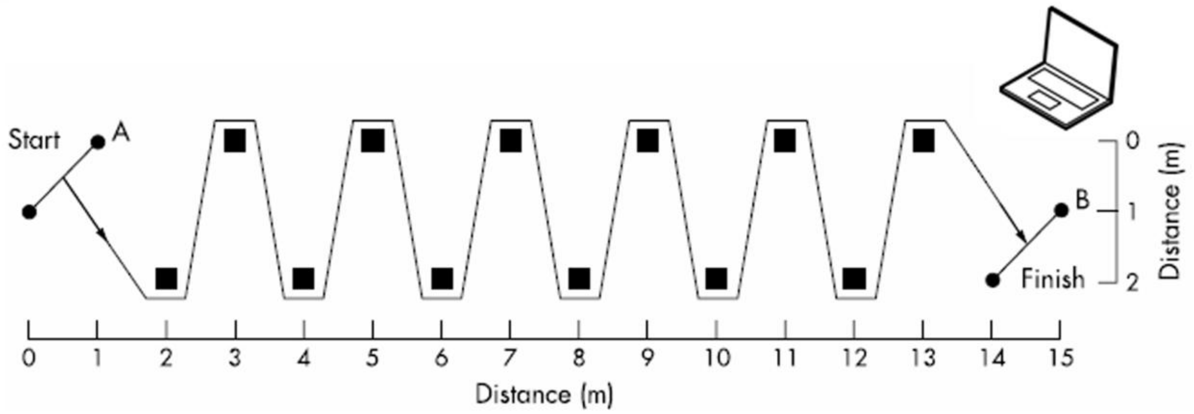

Figure 3.3. Graphical representation of the single- and dual-task dribble test (adapted from Lemmink et al., 2004).

3.2.3.4 Decision-making measurement

Participants' perceptual-cognitive skills were assessed via an interactive decision-making test. Participants completed 20 trials where they performed a short dribble of 5m and then passed the ball to a teammate (projected on a near life-size screen distanced 5m from the participant) (see Figure 3.4). On the screen, 3v2, 4v3 and 5v4 offensive action scenarios were projected from the participants' viewing perspective. Participants were scored based on the correctness of their decision. The correct decision was defined by agreement between six high performance coaches. Only scenarios with an overall coach agreement above 80% were used.

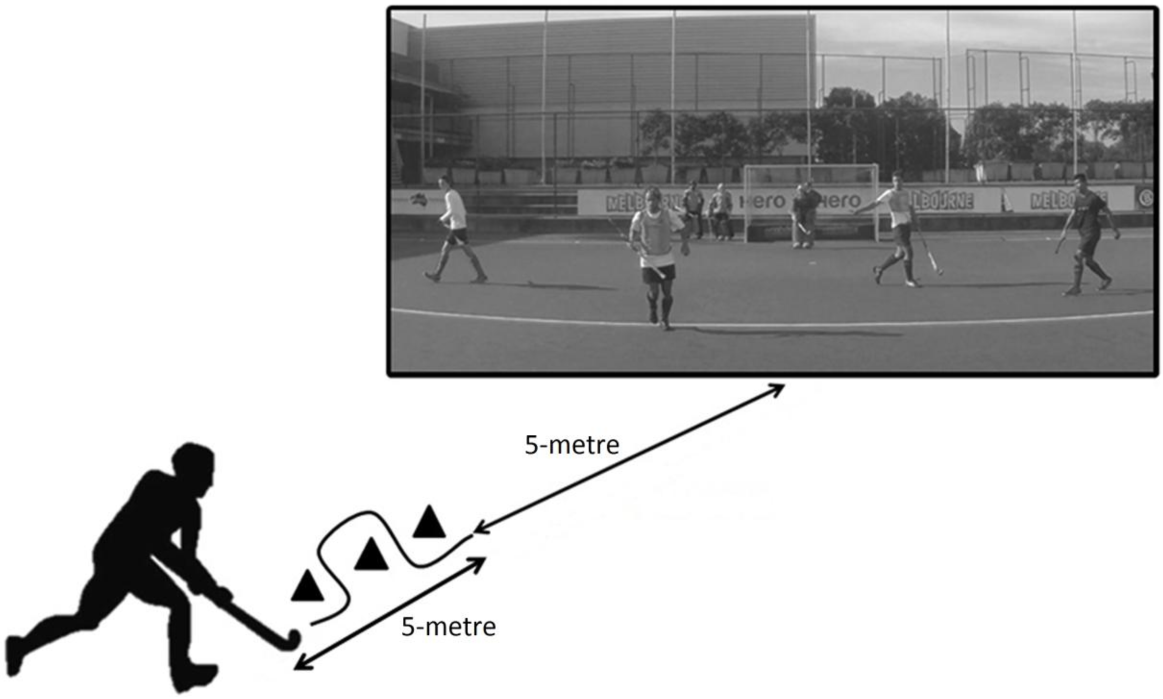

Figure 3.4. Graphical representation of the decision-making test.

3.2.3.5 Self-Regulation measurement

To measure the extent to which participants are proactive in their learning process, the Self-Regulated Learning Self-Report Scale (SRL-SRS) (Toering, Elferink-Gemser, Jonker, van Heuvelen, & Visscher, 2012) was used (see Appendix D). This questionnaire consisted of 46 items, focussing on six different sub-factors: planning, monitoring, effort, self-efficacy, evaluation and reflection. After the purpose of the questionnaire was explained by the researcher, participants were then asked to complete the questionnaire individually. On average, participants took 10 minutes to complete the questionnaire and data was considered per sub-factor. Test-retest reliability (ICC) of all subscales of the self-regulation questionnaire varied between 0.69 and 0.84; suggesting that all subscales had relative temporal stability, except for self-monitoring (Toering et al., 2012).

3.2.3.6 Sport History measurement

A modified version of the Developmental History of Athletes Questionnaire (DHAQ) (Hopwood, 2013) was used to gain an understanding of the participants prior developmental sport experiences that may have influenced their field hockey skill expertise. From the original DHAQ, the following sections were used in this study: 'your representative history', 'your practice history' (excluding the 'mental preparation' section) and 'your participation in other organised sports' (see Appendix C). After the researcher explained the purpose of the questionnaire, participants were then asked to complete the questionnaire individually. On average, participants took 20 minutes to complete the questionnaire. Test-retest reliability (ICC) of all sections of the DHAQ varied between 0.65 and 0.99; suggesting that all sections had relative temporal stability (Hopwood, 2013).

3.2.3.7 Birth distribution

To create an equal competition, players are divided into age groups. In this sample, to be eligible for the U13 group, players had to be born between 1 January 2002 and 31 December 2003. For the U15 group, players had to be born between 1 January 2000 and 31 December 2001 and for the U18 group, players had to be born between 1 January 1997 and 31 December 1999. The birth distribution was then analysed by dividing the players into four quartiles of 6 months based on their birth date. Players born from 1 January to 30 June of the first year of their age group were in the first quartile (Q1), players born from 1 July to 31 December of the first year of their age group were in the second quartile (Q2), players born from 1 January to 30 June of the second year of their age group were in the third quartile (Q3) and players born from 1 July to 31 December of the second year of their age group were in the fourth quartile (Q4). As the U18 group included players across three years, players born in the third year were also placed in Q4.

The passing test, hitting test and decision-making test were new tests and therefore their test-retest-reliability was determined. A total of 10 players with an average age of 13.2 (±0.4) years performed the passing, hitting and decision-making tests on two different occasions two weeks apart. Intraclass correlation coefficients (ICC's) were determined for the passing and hitting test, the accuracy score and completion time were analysed and for the decision-making test the decision-score percentage was analysed. ICC for passing accuracy score was 0.622 (p=0.018) and for passing time was 0.746 (p=0.001). ICC for hitting accuracy score was -0.133 (p=0.624) and for hitting time was -0.089 (p=0.605). ICC for decision-making score was 0.226 (p=0.267). Indicating that the results of the hitting test and decision-making test should be interpreted with caution.

3.2.4 Data analysis

Mean scores and standard deviations were calculated for each variable of the different tests completed across each age/skill group (see Table 3.2 for males and Table 3.3 for females). A gender specific multivariate analysis of covariance (MANCOVA) was performed (with playing level and age group as factors) to determine the effect of playing level and age group on test performance. Chronological age was used as a covariate to control for the potential influence of growth and development on the performance characteristics. To determine which performance characteristics discriminated the best between state and club level players, a stepwise discriminant function analysis was performed. In this analysis, playing level was used as dependent variable and all the performance characteristics were the independent variables. The assumption of homogeneity of variance was violated between the different age groups and this should be taken into account when interpreting the differences between the age groups. However, the effect of violating this assumption in a MANCOVA analysis is unclear. Where appropriate, follow up analysis with Bonferroni corrections were performed. To calculate the effect size, a partial eta squared (η_p^2) was used, the descriptive terms were: small effect = 0.01, medium effect = 0.06 and large effect = 0.14 (Cohen, 1988). The distribution of birth dates was compared with the use of a chi-square test. Significance level was set at $p<0.05$.

3.3 Results

3.3.1 Males

The results of the MANCOVA for males showed a significant main effect for playing level ($F(31,74) = 2.487$, $p = 0.001$; Wilk's $\Lambda = 0.49$, $\eta_p^2 = 0.51$) and a significant main effect for age group ($F(62,148) = 1.554$, $p = 0.016$; Wilk's $\Lambda = 0.37$, $\eta_p^2 = 0.39$) but no significant playing level x age group interaction ($F(62,148) = 1.063$; $p = 0.376$; Wilk's $\Lambda = 0.48$, $\eta_p^2 = 0.31$). The univariate analyses of covariance revealed significant differences between state and club level players for one anthropometric variable: age at PHV ($F(1,104)=6.80$, $p = 0.010$, $\eta_p^2 = 0.06$). Two physical capacity measurements revealed significant differences; 5m sprint time ($F(1,104) = 4.63$, $p = 0.034$, $\eta_p^2 = 0.4$) and VO_2max ($F(1,104) = 19.11$, $p < 0.000$, $\eta_p^2 = 0.16$). Significant differences were also found for six sport-specific technical skill measurements; passing accuracy ($F(1,104) = 4.52$, $p = 0.036$, $\eta_p^2 = 0.04$), passing time ($F(1,104) = 5.12$, $p = 0.026$, $\eta_p^2 = 0.05$), hitting accuracy ($F(1,104) = 13.94$, $p < 0.001$, $\eta_p^2 = 0.12$), hitting time ($F(1,104) = 4.98$, $p = 0.028$, $\eta_p^2 = 0.05$), single-task dribble time ($F(1,104) = 18.68$, $p < 0.001$, $\eta_p^2 = 0.15$) and dual-task dribble time ($F(1,104) = 22.32$, $p < 0.001$, $\eta_p^2 = 0.18$). The decision-making test revealed a significant difference between state and club level players ($F(1,104) = 16.24$, $p < 0.001$, $\eta_p^2 = 0.14$). Analyses of the sport history variables revealed significant differences for three variables: playing experience ($F(1,104) = 8.38$, $p = 0.005$, $\eta_p^2 = 0.07$), hours of hockey training ($F(1,104) = 13.47$, $p < 0.001$, $\eta_p^2 = 0.12$) and hours of physical training ($F(1,104) = 10.04$, $p = 0.002$, $\eta_p^2 = 0.01$). Where a significant difference existed between the state and club level players, the state players always scored better than the club level players. No significant differences between state and club level players were found for any aspects of self-regulation.

Follow up analyses with the use of ANOVA with Bonferroni correction were used to determine the significant differences between state and club level players within age groups for the significant performance variables. For the U13 age group, the following variables revealed a significant difference: VO_2max ($F(1,49) = 21.94$, $p < 0.001$), passing time ($F(1,49) = 13.04$, $p = 0.001$), single-task dribble time ($F(1,49) = 25.46$, $p < 0.001$), dual-task dribble time ($F(1,49) = 26.10$, $p < 0.001$), decision-making ($F(1,49) = 14.92$, $p < 0.001$) and playing experience ($F(1,49) = 22.79$, $p < 0.001$). No significant differences were found within the U15 and U18 age groups.

Table 3.2. Mean (±SD) of physical capacity, sport-specific technical skill, perceptual-cognitive skill, self-regulation and sport history variables for male state and club level players and the MANCOVA comparison between playing levels.

	U13		U15		U18		MANCOVA	
	State (n=24)	Club (n=26)	State (n=19)	Club (n=27)	State (n=6)	Club (n=9)	$F(1,104)$	p
Physical capacity								
Flexibility	-3.1 (6.2)	3.4 (11.3)	-1.8 (6.5)	-1.4 (9.5)	-0.2 (5.7)	-0.2 (9.4)	0.45	0.502
Grip strength	23.3 (4.2)	22.0 (5.7)	31.6 (7.0)	34.2 (9.4)	45.6 (8.2)	44.3 (6.1)	0.32	0.572
Peak Power (W)	3933.3 (484.0)	3645.0 (692.8)	5007.3 (577.1)	4882.4 (733.8)	6350.9 (289.1)	5675.4 (581.4)	3.24	0.075
Sprint 5m (sec)	1.17 (0.07)	1.24 (0.09)	1.14 (0.07)	1.12 (0.08)	1.01 (0.03)	1.10 (0.09)	4.63	0.034
Sprint 20m (sec)	3.59 (0.19)	3.80 (0.32)	3.39 (0.15)	3.38 (0.23)	3.11 (0.12)	3.30 (0.19)	3.04	0.084
Agility (sec)	8.07 (0.38)	8.61 (2.03)	8.10 (0.71)	8.19 (0.68)	7.69 (0.46)	8.45 (0.52)	1.43	0.235
VO_2max (ml.kg^{-1}.min^{-1})	48.6 (5.6)	38.8 (8.7)	49.6 (4.4)	46.9 (4.8)	54.2 (5.5)	45.9 (4.8)	19.11	<0.001
Sport-specific technical skill								
Passing accuracy	16.0 (2.9)	13.4 (3.2)	16.2 (4.3)	15.3 (3.9)	17.3 (1.9)	15.3 (2.2)	4.52	0.036
Passing time (sec)	20.9 (1.8)	25.9 (6.5)	20.5 (1.9)	21.6 (2.8)	18.3 (1.8)	19.8 (2.4)	5.12	0.026
Hitting accuracy	8.0 (2.8)	5.7 (3.0)	9.1 (3.7)	6.8 (2.6)	11.9 (6.9)	7.9 (4.3)	13.94	<0.001
Hitting time (sec)	25.3 (1.8)	31.9 (8.1)	25.4 (2.2)	27.0 (4.5)	24.0 (2.1)	25.2 (2.3)	4.98	0.028
Single-task dribble time (sec)	19.5 (1.5)	25.0 (5.1)	16.5 (1.4)	21.6 (3.7)	18.4 (1.4)	21.8 (2.9)	18.68	<0.001
Dual-task dribble time (sec)	21.0 (1.9)	27.3 (5.8)	20.0 (1.6)	22.6 (3.7)	19.0 (1.5)	23.0 (2.9)	22.32	<0.001
Dribble delta	1.4 (1.3)	2.3 (2.3)	0.5 (1.0)	1.0 (1.5)	0.6 (0.9)	1.2 (1.1)	2.70	0.104
Dual-task colour score (%)	99.4 (2.1)	97.8 (3.5)	98.1 (4.2)	98.3 (3.7)	99.0 (2.5)	98.6 (4.2)	0.32	0.573
Perceptual-cognitive skill								
Decision-making score (%)	55.3 (7.1)	46.7 (8.6)	59.5 (9.1)	56.3 (9.6)	66.7 (9.8)	52.4 (10.1)	16.24	<0.001
Self-regulation								
Planning (1-4)	2.8 (0.4)	2.6 (0.4)	2.5 (0.5)	2.6 (0.5)	3.0 (0.5)	2.5 (0.7)	2.22	0.140
Monitoring (1-4)	3.1 (0.5)	2.9 (0.4)	3.0 (0.6)	2.9 (0.6)	3.3 (0.4)	3.0 (0.4)	1.20	0.275
Effort (1-4)	3.4 (0.4)	3.4 (0.5)	3.3 (0.5)	3.4 (0.4)	3.5 (0.4)	3.0 (0.5)	1.26	0.265
Self-efficacy (1-4)	3.1 (0.4)	3.0 (0.4)	2.9 (0.5)	3.0 (0.4)	3.3 (0.5)	3.1 (0.3)	0.29	0.590
Evaluation (1-5)	3.9 (0.6)	3.7 (0.4)	3.8 (0.7)	3.8 (0.6)	4.2 (0.4)	3.8 (0.5)	1.19	0.277
Reflection (1-5)	4.3 (0.6)	4.2 (0.3)	4.3 (0.3)	4.2 (0.5)	4.6 (0.2)	4.2 (0.4)	2.29	0.133
Sport history								
Playing experience (years)	6.5 (0.9)	4.4 (2.0)	6.0 (1.6)	5.4 (2.8)	8.9 (2.1)	6.8 (3.3)	8.38	0.005
Hockey training (hours)	1215.6 (1323.8)	371.1 (432.2)	1198.6 (461.8)	913.5 (717.3)	2435.2 (898.1)	1367.8 (954.6)	13.47	<0.001
Physical training (hours)	162.0 (239.3)	99.9 (236.6)	573.3 (780.0)	276.3 (470.0)	1019.7 (1033.1)	220.9 (321.4)	10.04	0.002
Informal play (hours)	634.5 (1049.3)	146.1 (203.4)	477.9 (489.5)	326.1 (424.5)	402.5 (375.1)	488.4 (770.5)	1.07	0.304
Different sports	3.0 (1.5)	2.2 (1.5)	2.8 (0.8)	2.4 (1.6)	2.3 (0.5)	2.7 (1.6)	0.76	0.385
Different sports training (hours)	544.5 (444.2)	431.3 (570.3)	1068.2 (1155.0)	786.3 (828.2)	964.6 (60.2)	1249.9 (2095.0)	0.05	0.816

3.3.2 Females

The results of the MANCOVA for females did not reveal a significant main effect for playing level ($F(31,57) = 1.585$, $p = 0.066$; Wilk's $\Lambda = 0.54$, $\eta_p^2 = 0.46$), no significant main effect for age group ($F(62,114) = 1.126$, $p = 0.289$; Wilk's $\Lambda = 0.39$, $\eta_p^2 = 0.38$) and no significant playing level x age group interaction ($F(62,114) = 0.945$, $p = 0.591$; Wilk's $\Lambda = 0.44$, $\eta_p^2 = 0.34$). Despite the absence of these main effects, univariate analyses of covariance revealed significant differences between state and club level players for one anthropometric variable: age at PHV ($F(1,87) = 20.50$, $p <0.000$; $\eta_p^2 = 0.19$). Two physical capacity measurements revealed significant differences: agility ($F(1,87) = 7.31$, $p = 0.008$; $\eta_p^2 = 0.08$) and VO_2max ($F(1,87) = 5.58$, $p = 0.020$; $\eta_p^2 = 0.06$). A total of four sport-specific technical skill measurements revealed significant differences: passing accuracy ($F(1,87) = 9.38$, $p = 0.003$, $\eta_p^2 = 0.10$), hitting time ($F(1,87) = 8.61$, $p = 0.004$, $\eta_p^2 = 0.09$), single-task dribble time ($F(1,87) = 14.83$, $p <0.001$, $\eta_p^2 = 0.15$) and dual-task dribble time ($F(1,87) = 11.91$, $p = 0.001$, $\eta_p^2 = 0.12$). Analyses of the sport history variables revealed a significant difference between state and club level players for playing experience ($F(1,87) = 8.09$, $p = 0.006$; $\eta_p^2 = 0.09$). Where a significant difference existed between the state and club level players, the state players always scored better than the club level players. No significant differences between state and club level players were found on the decision-making test or self-regulation.

Follow up analyses with the use of ANOVA with Bonferroni correction were used to determine the significant differences between state and club level players within age groups for significant performance variables. For the U13 age group, single-task dribble time ($F(1,38) = 17.61$, $p <0.001$) revealed a significant difference while for the U15 age group, the following variables revealed significant differences: passing accuracy ($F(1,49) = 14.10$, $p = 0.001$) and dual-task dribble time ($F(1,39) = 12.50$, $p = 0.001$). No significant differences were found for the U18 age group.

Table 3.3. Mean (±SD) of physical capacity, sport-specific technical skill, perceptual-cognitive skill, self-regulation and sport history variables for female state and club level players and the MANCOVA comparison between playing levels.

	U13		U15		U18		MANCOVA	
	State (n=18)	Club (n=21)	State (n=24)	Club (n=16)	State (n=9)	Club (n=6)	$F(1,87)$	p
Physical capacity								
Flexibility	5.3 (6.7)	5.7 (8.3)	4.8 (8.4)	6.3 (6.9)	4.8 (4.0)	8.2 (9.2)	0.89	0.348
Grip strength	26.2 (7.3)	23.5 (4.7)	28.0 (4.7)	28.6 (8.1)	30.8 (3.7)	28.1 (5.0)	0.72	0.396
Peak Power (W)	3890.3 (470.8)	3845.6 (536.5)	4603.4 (452.3)	4737.0 (495.7)	5319.6 (318.2)	4935.0 (454.1)	0.19	0.661
Sprint 5m (sec)	1.23 (0.05)	1.24 (0.08)	1.14 (0.07)	1.18 (0.12)	1.10 (0.06)	1.15 (0.12)	2.09	0.151
Sprint 20m (sec)	3.66 (0.19)	3.74 (0.25)	3.48 (0.15)	3.61 (0.38)	3.41 (0.09)	3.51 (0.30)	2.29	0.134
Agility (sec)	8.31 (0.39)	8.99 (0.95)	7.76 (1.70)	8.84 (1.23)	8.18 (0.36)	8.70 (0.55)	7.31	0.008
VO_2max ($ml.kg^{-1}.min^{-1}$)	43.3 (6.5)	38.3 (5.0)	45.1 (5.2)	41.0 (5.6)	45.0 (4.4)	43.8 (8.9)	5.58	0.020
Sport-specific technical skill								
Passing accuracy	14.8 (2.5)	12.9 (3.5)	17.4 (2.5)	14.3 (2.6)	16.6 (1.9)	15.6 (2.2)	9.38	0.003
Passing time (sec)	22.0 (1.9)	25.4 (5.4)	22.2 (3.1)	21.4 (3.3)	19.9 (2.0)	21.6 (1.2)	1.87	0.174
Hitting accuracy	6.6 (2.3)	4.9 (2.5)	6.9 (3.3)	6.8 (3.2)	8.1 (2.4)	6.4 (2.1)	3.09	0.082
Hitting time (sec)	26.3 (2.0)	30.7 (5.8)	25.8 (1.8)	27.1 (4.2)	23.3 (1.4)	25.7 (2.1)	8.61	0.004
Single-task dribble time (sec)	21.0 (1.1)	24.0 (2.9)	20.3 (1.7)	21.4 (2.2)	19.1 (1.3)	20.5 (0.6)	14.83	<0.001
Dual-task dribble time (sec)	23.0 (2.5)	25.7 (3.9)	20.8 (2.0)	23.3 (2.4)	20.1 (1.5)	21.8 (0.9)	11.91	0.001
Dribble delta	2.0 (2.0)	1.7 (2.3)	0.5 (2.4)	1.8 (1.1)	1.0 (0.5)	1.2 (1.1)	0.45	0.504
Dual-task colour score (%)	97.6 (6.1)	96.8 (4.8)	97.0 (6.5)	98.3 (4.4)	95.1 (8.3)	99.0 (2.5)	1.18	0.280
Perceptual-cognitive skill								
Decision-making score (%)	55.1 (10.9)	51.4 (13.7)	59.1 (9.1)	51.1 (10.6)	62.3 (5.9)	63.1 (5.4)	1.90	0.171
Self-regulation								
Planning (1-4)	2.7 (0.5)	2.7 (0.6)	2.8 (0.6)	2.8 (0.5)	2.6 (0.6)	2.9 (0.3)	0.47	0.494
Monitoring (1-4)	3.2 (0.5)	3.1 (0.4)	3.2 (0.5)	3.2 (0.6)	3.1 (0.5)	2.9 (0.3)	0.72	0.398
Effort (1-4)	3.6 (0.4)	3.4 (0.4)	3.5 (0.4)	3.5 (0.4)	3.3 (0.5)	3.4 (0.5)	0.22	0.643
Self-efficacy (1-4)	3.3 (0.4)	3.1 (0.4)	3.1 (0.5)	3.1 (0.5)	3.0 (0.4)	3.0 (0.3)	0.61	0.436
Evaluation (1-5)	4.2 (0.5)	3.9 (0.6)	3.9 (0.6)	4.0 (0.5)	3.9 (0.5)	4.0 (0.5)	>0.01	0.984
Reflection (1-5)	4.6 (0.4)	4.2 (0.5)	4.3 (0.3)	4.4 (0.4)	4.4 (0.3)	4.2 (0.4)	2.38	0.126
Sport history								
Playing experience (years)	5.7 (1.1)	4.2 (2.1)	6.9 (1.7)	6.1 (1.9)	9.6 (1.9)	7.8 (3.0)	8.09	0.006
Hockey training (hours)	911.1 (456.5)	598.3 (415.9)	1236.6 (710.5)	1159.1 (944.3)	1420.2 (604.6)	1041.6 (324.1)	2.23	0.138
Physical training (hours)	128.6 (233.4)	116.9 (135.4)	487.8 (793.4)	383.8 (676.5)	607.7 (1275.0)	321.9 (277.0)	0.81	0.370
Informal play (hours)	126.7 (142.3)	151.4 (240.3)	311.8 (454.5)	226.2 (248.5)	272.8 (421.7)	213.4 (318.3)	0.21	0.655
Different sports	2.3 (1.4)	2.0 (1.2)	2.2 (1.3)	2.0 (1.2)	1.4 (1.7)	1.0 (1.3)	1.24	0.268
Different sports training (hours)	782.2 (925.9)	608.4 (559.9)	650.9 (638.6)	607.8 (530.9)	603.7 (769.4)	602.1 (914.3)	0.07	0.796

3.3.3 Effect of covariate

Chronological age appeared to have a significant effect for both males ($F(31,74) = 7.621$, $p < 0.001$; Wilk's $\Lambda = 0.24$, $\eta_p^2 = 0.76$) and females ($F(31,57) = 4.292$, $p < 0.001$; Wilk's $\Lambda = 0.30$, $\eta_p^2 = 0.70$). For the males, age had an influential effect on all the anthropometric variables (except age at PHV), all the physical capacity variables, four sport-specific technical skill variables (passing time, hitting time and single- & dual-task dribbling time), the self-regulation sub-factor monitoring and the amount of playing experience. For the females, age had an influential effect on two anthropometric variables (height, weight), all physical capacity variables except for agility and VO_2max, four sport-specific technical skill variables (passing time, hitting time and single- & dual-task dribbling time) and playing experience. In simple terms this means that for the above stated variables, the scores on these variables improved with age.

3.3.4 Discriminant function analysis

Results of the stepwise discriminant analysis are presented in table 3.4. The model for boys demonstrated that three variables (dual-task dribble time, grip strength and hitting accuracy) optimally discriminate between state and club level players. These three variables correctly classified 71.2% of the players as state or club level players. This is an improvement of 21.2% above chance. The model for girls also demonstrated that three variables (single-task dribble time, passing accuracy and age at PHV) optimally discriminate between state and club level players. These three variables correctly classified 75.5% of the players as state or club level players. This is an improvement of 25.5% above chance.

Table 3.4 Summary of stepwise discriminant analysis, variables entered.

Step	Entered	Wilks' Lambda							
						Exact F			
		Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
Boys									
1	Dual-task dribble time	0.779	1	1	109	30.951	1	109	<0.001
2	Grip strength	0.740	2	1	109	18.955	2	108	<0.001
3	Hitting accuracy	0.712	3	1	109	14.442	3	107	<0.001
Girls									
1	Single-task dribble time	0.792	1	1	92	24.181	1	92	<0.001
2	Passing accuracy	0.734	2	1	92	16.525	2	91	<0.001
3	Age at PHV	0.682	3	1	92	13.968	3	90	<0.001

Note: At each step, the variable that minimizes the overall Wilks' Lambda is entered. Maximum number of steps is 64, minimum partial F to enter is 3.84, maximum partial F to remove is 2.71 and F level, tolerance, or VIN insufficient for further computation.

3.3.4 Birth distribution

The distribution of birth dates of male state level and club level players for the U13, U15 and U18 group are shown in Figures 3.5a, 3.6a and 3.7a respectively. Results of the chi-square test revealed no significant differences between the birth distribution of male state and club level players in the U13 group ($\chi^2(3) = 6.53$, $p = 0.089$), in the U15 group ($\chi^2(3) = 1.95$, $p = 0.582$) and in the U18 group ($\chi^2(3) = 0.23$, $p = 0.893$). The distribution of birth dates of female state level and club level players for the U13, U15 and U18 group are shown in Figures 3.5b, 3.6b and 3.7b respectively. Results of the chi-square test revealed no significant differences between the birth distribution of female state and club level players in the U13 group ($\chi^2(3) = 3.59$, $p = 0.309$), in the U15 group ($\chi^2(3) = 1.24$, $p = 0.743$) and in the U18 group ($\chi^2(3) = 6.67$, $p = 0.083$).

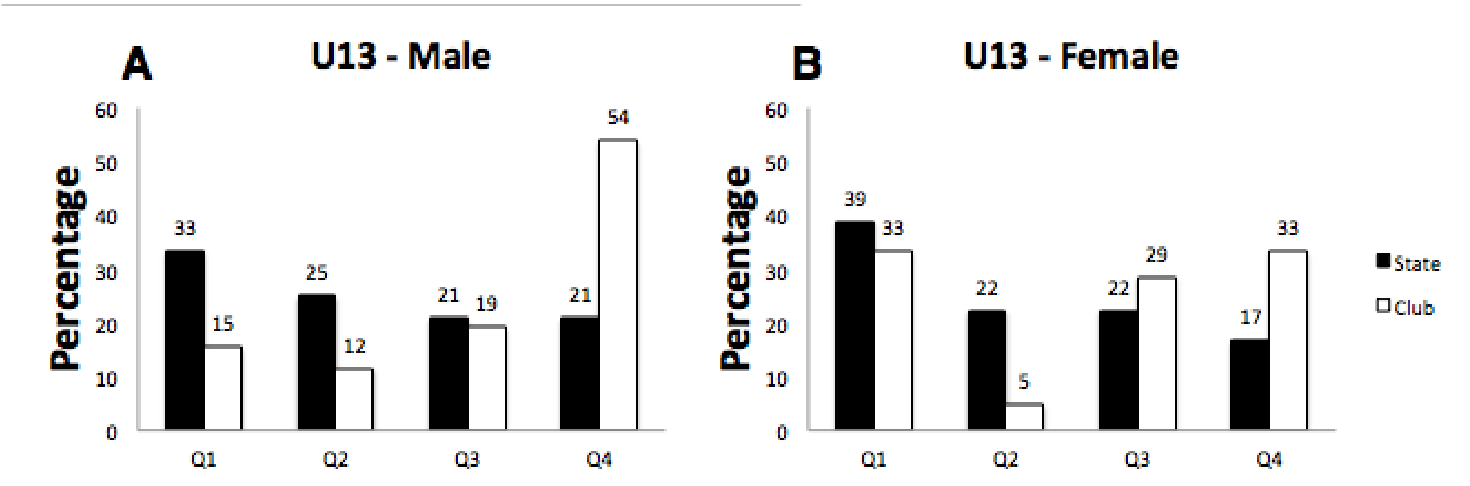

Figure 3.5. Birth distribution of the state and club level players of the U13 age group for a) males and b) females.

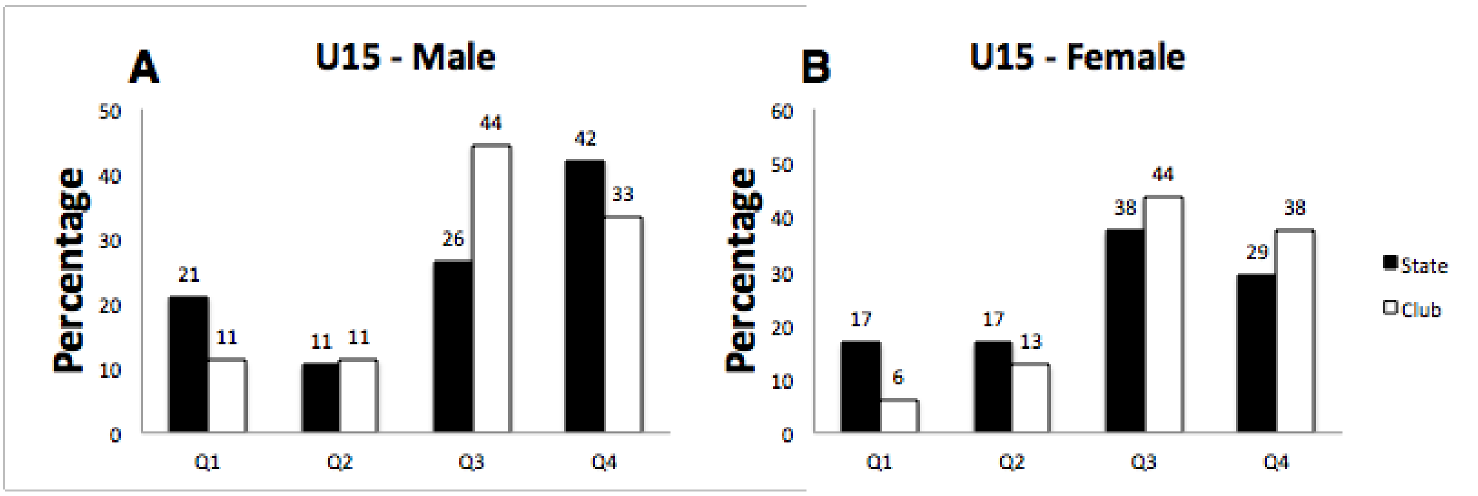

Figure 3.6. Birth distribution of the state and club level players of the U15 age group for a) males and b) females.

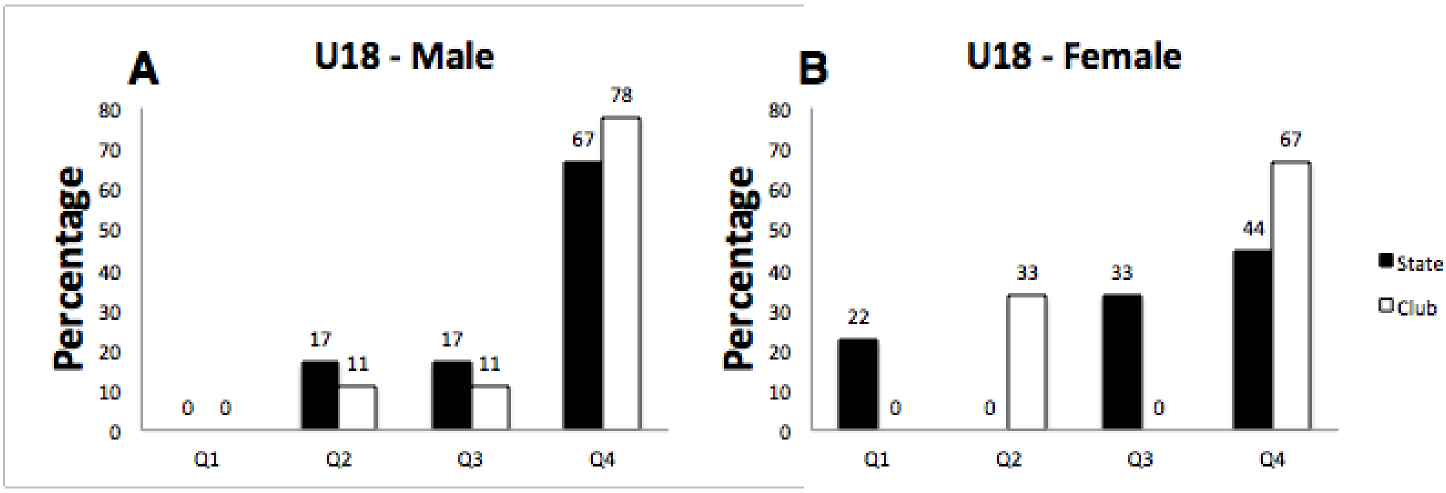

Figure 3.7. Birth distribution of the state and club level players of the U18 group for a) males and b) females.

3.3.5 Field hockey practice per year

Figure 3.8 shows the field hockey practice hours per year for all state and club level players. Results of the one-way ANOVA revealed a significant difference in the field hockey practice hours per year between state and club level players at the age of 10 years old ($F(1,177) = 3.93$, $p = 0.049$), 11years old ($F(1,177) = 6.97$, $p = 0.009$), 12 years old ($F(1,165) = 3.92$, $p = 0.049$) and 13 years old ($F(1,127) = 4.44$, $p = 0.037$) (see Figure 3.8). No significant differences between state and club level players were found for any other ages. At each year level that was significantly different state level players had accumulated more field hockey specific training than the club level players.

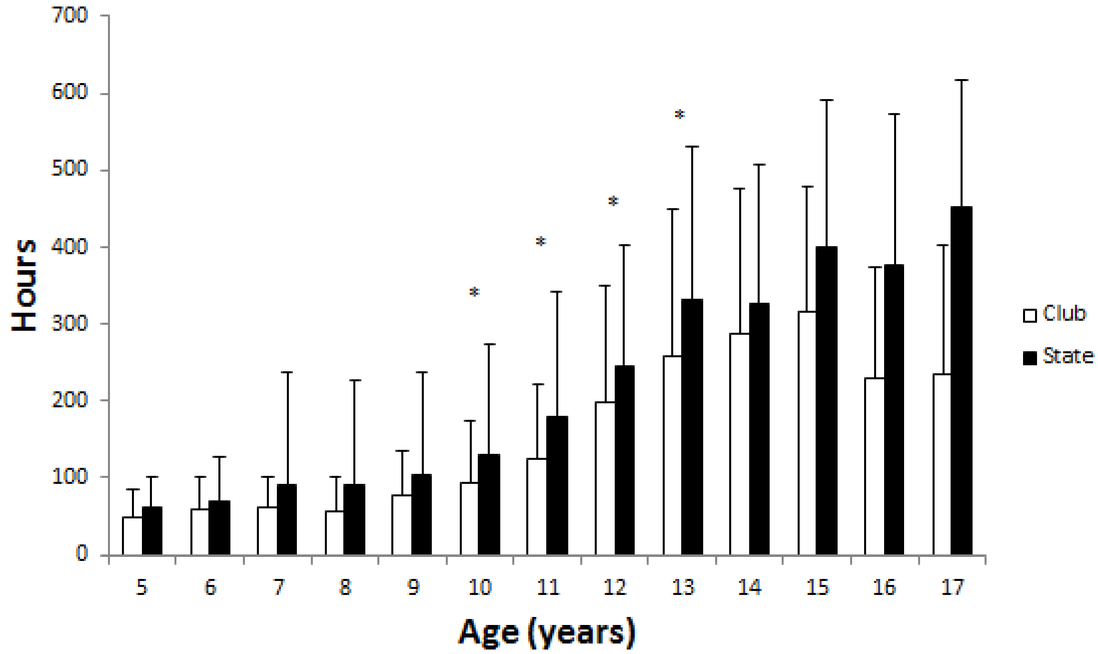

Figure 3.8. Field hockey specific training hours per age for state and club level players. * $p<0.05$.

3.4 Discussion

The aim of this study was to determine what kind of performance characteristics distinguish between skill levels at different development stages in field hockey using a holistic testing battery. This cross-sectional approach was used to determine the key differences in anthropometric, physical capacity, sport-specific technical skill, decision-making, self-regulation and sport history characteristics. Results showed that for the males, state level players outperformed their club level peers on age at PHV, sprint speed, endurance, passing accuracy, passing time, hitting accuracy, hitting accuracy, single-task dribble time, dual-task dribble time, decision-making, playing experience, total hours of hockey training and total hours of physical training. For the females, no main effect of playing level was present, however, results showed that state level players outperformed their club level peers on age at PHV, agility, endurance, passing accuracy, hitting time, single-task dribble time, dual-task dribble time and playing experience. Interestingly, no differences were found between the self-regulatory skills of state and club level players for either gender.

First, consistent with previous literature (Elferink-Gemser et al., 2004; Keogh et al., 2003; Nieuwenhuis et al., 2002), the current results demonstrated that dribble skill discriminates most between state and club level players. However, the emergence of differences between club and state level players differed between males and females with dribbling skills seemingly perceived by talent selectors as more important for male players. Secondly, the ability to pass or hit the ball accurately and quickly to a target differed significantly between playing levels. However, it seems that the ability to hit the ball to a target is not as important for female players as it is for male players. Thirdly, state players outperformed their club level peers on endurance and speed measurements. State level males scored significantly better on the sprint test and the multistage shuttle run test while the state level females scored significantly better on the agility test and the multistage shuttle run test. The importance of speed and endurance abilities has also been previously reported when comparing the physical demands of national and international competition levels (Jennings, Cormack, Coutts, & Aughey, 2012a). Interestingly, only male state players outperformed their club level players on the decision-making test and no differences in self-regulatory skills were found between state and club level players. From the results of this study, and particularly the results of the discriminant function analysis and guidelines provided for selection by Hockey Australia (retrieved from http://aussiehockey.com.au/coaching/, April 2017), it can be concluded that expert field hockey selectors and coaches in Australia consider dribbling skills, passing/hitting skills and speed and endurance capacities as the most important characteristics to possess for a youth field hockey player to be able to compete at the highest level of competition.

Although most differences between club and state level players are similar for males and females players, some gender differences are apparent in this study. Firstly, as expected, female players have their PHV at an earlier age than male players and this is reflected in some of the physical capacity measurements (Sherar, Mirwald, Baxter-Jones, & Thoms, 2005). Furthermore, results of the discriminant function analysis seemed to suggest that the growth spurt has more impact on performance levels in female players. When all players have had their growth spurt, growth related differences in physical capacity are minimised which is reflected in a measurement such as speed (5 & 20m sprint); differences between playing levels for this measurement are minimised in the female U13 group and in the male U15 group compared to differences between playing levels in the other age groups. Secondly, male state level players outperformed their club level players on more performance characteristics, although it didn't always reach statistical significance, compared to female state level players. It could be argued that the significant differences in deliberate hockey and physical practice between male state and club level players account for this bigger difference between skill levels. Thirdly, it could be argued that the smaller differences between female state and club level players in physical capacities and sport-specific technical skills suggest that other performance characteristics such as psychological traits (albeit not self-regulation) or tactical skills are more important to be selected into a representative team for female players (Elferink-Gemser, Kannekens, Lyons, Tromp, & Visscher, 2010; Oliver, Hardy, & Markland, 2010).

Findings could imply that coaches and trainers should focus on developing dribbling skills, passing/hitting skills and speed and endurance capacities of young field hockey players for them to be able to play at the highest level of competition. However, it can't be concluded from this study that these performance characteristics translate to future sporting success (Abbott et al., 2005). Although state players are considered as 'talented' players, it is unclear from this study if these players eventually become expert athletes at the senior level. To draw this conclusion, a longitudinal research approach has to be adopted which has shown to be successful in identifying performance characteristics that predict future sporting success in sports such as rugby league and water polo (Falk, Lidor, Lander, & Lang, 2004; Till et al., 2015).

Although it can be concluded that speed and endurance are perceived as important characteristics for field hockey players, it has to be noted that speed and endurance capacities of 11-16 year old athletes are strongly influenced by the maturational status of an athlete (Pearson, Naughton & Torode, 2006). Indeed, maturational status was also influential in this study as the state level players experienced their PHV significantly earlier than club level players which is consistent with research investigating the relationship between maturational status and physical capacity in sports such as Australian football, basketball and soccer (Coelho E Silva, Figuierdo, Moreira Carvalho, & Malina, 2008; Gastin & Bennet, 2014; Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004). In addition to the finding that state level players matured earlier, the birth distribution of the male U13 group showed that, although not significant, there was an underrepresentation of club level players in the first two quartiles and an overrepresentation of club level players in the last two quartiles relative to the state level players (see Figure 3.5a). Firstly, this implies that selected U13 male players are older and physically more mature which could lead to a difference in biological age of two to three years (Malina, Bouchard, & Bar-Or, 2004). Secondly, this could imply that U13 male state level players were picked for representative teams based on their maturational and relative age advantage. Two possibilities to account for the relative age advantage are the use of age-ordered (chronological and/or biological age) bib numbers during selection trials (Mann & van Ginneken, 2016) or a 21 month grouping system for competition (Helsen et al., 2012).

A second factor that could potentially have a major influence on the performance of a player is his/her sporting history. Results from the sport history questionnaire revealed that state players had significantly more playing experience and the state males also reported significantly more deliberate hockey practice and physical practice while a clear trend was apparent for the state level females with the accrual of more hours of specific hockey practice and physical training. These results suggest that state players have better field hockey skills and physical capacity due to the amount of hockey specific practice they have accumulated and are not necessarily the players with the greatest potential to further develop their talent.

An addition to previous testing batteries was a perceptual-cognitive measurement as it has been demonstrated it is a key difference between skilled and lesser skilled team-sport players (Savelsbergh et al., 2010; Ward & Williams, 2003). Findings revealed that male state players scored significantly higher than club level players however, significant differences between female players did not emerge. Despite the lack of a significant different between female players, clear differences in decision-making scores between state and club level players are apparent for the U13 and U15 group but this trend disappeared in the U18 group which influenced the overall statistical effects reported. It should also be noted that the decision-making score was solely based on the accuracy of the decision while it is clear from other research that expert and non-expert decision-makers also differ in visual search behaviour and response time (Mann, Williams, Ward, & Janelle, 2007).

The absence of differences in the self-regulatory skills of the athletes may be due to a number of factors. Firstly, coaches and selectors don't consider self-regulation as an important characteristic when selecting their representative squads. Seemingly a higher premium is placed on current levels of sport-specific technical skills (i.e., dribbling) and physical capacity (i.e., speed and endurance). This is in contrast to previous research where it has been shown that high performing soccer players possessed better self-regulatory skill then their less performing peers (Jonker et al., 2010; Toering et al., 2009) and that expert Gaelic football players possess greater self-regulatory skills as evidenced by greater skill improvement in a training session (Coughlan, Williams, McRobert, & Ford, 2014). Secondly, it could be argued that players gave socially desirable answers on the self-reported self-regulation questionnaire as club and state level players all reported similar self-regulatory scores as international level athletes (Jonker et al., 2010). To tackle the self-report bias, an observational tool was developed to measure self-regulatory skills in a soccer practice setting (Toering et al., 2011). Although some limitations of this observational tool were reported, it is suggested that this is a promising direction to objectively measure the self-regulatory skills of young athletes and potentially overcome the limitations of relying on self-report measures.

Based on the findings of the current study, it can be interpreted that experienced selectors and coaches select players for representative state teams predominantly based on their dribbling skills, passing/hitting skills and speed and endurance capacities. Although it is argued that one of the main questions during the talent identification and selection process is whether a young athlete can benefit from a development program (Williams & Reilly, 2000), it is clear that selection for such a training program is influenced by maturational status and accrued hockey specific training. Being an early maturer and having a greater amount of practice seems to provide a large advantage for being selected whilst it is not clear if these advantages promote the development of skills and translate to future sporting success. It is suggested that to improve the efficiency of talent selection, sporting organisations should consider a more training based selection program. That is, players who are selected based on performance testing in conjunction with coaches' subjective selections, are then able to demonstrate not only their current performance levels but potential 'talent' during a training program where their "coachability" and self-regulatory skills can be observed over a longer period of time. Final team selection can then be based on the overall performance during the training program, which may reduce the influence of selection based solely on maturational status and training history. This will increase the predictive value of talent selection, which will again enhance the cost efficiency of talent development and ultimately lead to the development of higher performing athletes.

The need for a selection procedure where the potential 'talent', "coachability" and self-regulatory skills of a young field hockey player can be observed is emphasized by the reliability of some of the used tests in the testing battery. A limitation of this study is that the reliability scores of the hitting and decision-making tests indicated that scores on these tests are not always consistent over a short period of time. Practically it means that a player can score high on the hitting test on one occasion and score low on the hitting test a week later. Therefore, selecting players solely based on the scores of these 'unreliable' tests is discouraged.

In conclusion, the selection of 'talented' players for a representative state team in Australia predominantly focused on dribbling skills, passing/hitting skills and speed and endurance capacities of young players. However, this study also highlighted differences between female and male state level players, indicating that different performance characteristics are deemed to be important for selection into a representative team. Furthermore, this study emphasised the need to consider the strong influence of maturational status and practice history when selecting players for a representative team as these factors don't translate to future sporting success.

Chapter Four

The effect of manipulating task constraints on game performance in youth field hockey

Abstract

The purpose of this study was to examine the influence of manipulating game constraints on match performance in youth field hockey. A total of 25 participants aged 10.6-14.6 years old played four different 25-minute games where density (228m^2 or 158m^2 per player) and/or number of players (11 per side or 8 per side) was manipulated. Match performance was determined by using notational analysis and physical demands were determined by using GPS analyses. Manipulating the number of players led to an increase in a successful passes (+ 2.68 passes), skilled actions (+ 3.73 skilled actions) and successful actions (+ 3.77 successful actions) performed per player and also created a more advantageous environment to enhance decision making. Increasing the density led to a decrease in unsuccessful dribbles (- 0.59 unsuccessful dribbles) played by children and an increase in high intensity running (+ 38 metres) and sprinting (+ 21.2 metres). The findings of this study provide an insight into the effect of manipulating task constraints in skilled junior field hockey and the findings highlight that all types of constraints influence emergent performance in their unique way and that coaches should consider these interactions to promote specific playing behaviour.

4.1 Introduction

Sporting organisations around the world are scaling equipment and the playing area to create appropriate competition circumstances for young athletes (Buszard, Reid, Masters, & Farrow, 2016). In the case of field hockey, the competition is structured according to the guidelines of the International Hockey Federation (FIH), where competition games for all age groups above 10 years old are played on a standard hockey pitch (91m long x 55m wide). Comparatively, competitive games for U10's hockey are played on a half-size pitch (55m long x 46m wide). On a standard hockey pitch, each team consists of 10 field players and one goalkeeper, while the U10 game is played with seven field players and one goalkeeper. Clearly, there are significant differences between the competitive games played at U10 relative to the game played at the very next age grouping of U12. Furthermore, coaches and trainers use small-sided games (SSG), to create more appropriate training environments, where the number of players and playing area are scaled to influence the technical and physiological demands of the game (Dellal, et al., 2011; Klusemann, Pyne, Foster, & Drinkwater, 2012; Davies, Young, Farrow, & Bahnert, 2013). It has been demonstrated that increasing the number of players in basketball and soccer led to an increase in the percentage of successful passes and a decrease in the number of passes and dribbles (Dellal, et al., 2011; Klusemann, et al., 2012). Whereas similar work in water polo revealed that an increase in number of players led to more passes and offensive actions (Lupo, et al., 2009) and in Australian football manipulating the numbers of players did not have any effect on technical actions (Davies, et al., 2013). Contradictory results can also be found for the effect of playing area on technical playing behaviour when sports such as rugby league, soccer and water polo are compared (Casamichana & Castellano, 2010; Gabbett, Abernethty & Jenkins, 2012; Lupo, et al., 2009). In summary, there is no clear evidence for the differences in the effect of task manipulations on playing behaviour between different sports and the underlying mechanism remains poorly understood.

A useful theoretical framework that may assist to explain differences in SSG research is the constraints-led approach. Newell (1986) emphasised that three different constraints (organismic, environmental and task) can all be independently manipulated to guide the acquisition of skill (Newell, Broderick, Deutsch, & Slifkin, 2003). Task constraints refer to the characteristics of a specific game such as rules, equipment and playing surfaces. Organismic constraints refer to the action capabilities and cognitive capabilities of a player and environmental constraints refer to characteristics of the surroundings such as altitude, noise and lighting.

An important feature of the constraints-led approach is the coupling between perception and action (Davids, 2010). Gibson (1979) argued that people are surrounded by energy flows which support decision-making and planning of movement. These energy flows contain specific information (affordances) about the environment that can then be used to reach a certain goal. Individuals can pick up these specific affordances and create specific information-movement couplings by becoming attuned to them. Two different processes are suggested to create these specific information-movement couplings

(Jacobs & Michaels, 2002). First individuals have to detect the critical information from all the stimuli that is available in the environment and then individuals have to calibrate their actions to this critical information. In SSG, different information is available compared to the adult game. For example, when field dimensions are manipulated, the relative personal playing area changes and can influence the amount of pressure players experience through a reduction in the time available to make a decision. Information-movement couplings may also be influenced by the amount of potential connections (passes) available based on the amount of players per side. An increase in number of players could increase the task complexity due to the increase in potential connections. Both factors can influence the available critical information that players can pick up to create a stable information-movement coupling and perform a successful action.

Whilst much has been learned from previous studies that have examined task constraints such as playing numbers and/or density on game dynamics in team-sports, several gaps in the literature remain. The aim of this study was to examine the impact of manipulating the number of players and relative playing density on performance variables, activity profiles and positional data in junior field hockey. As contradictory results are shown for the effect of manipulating the number of players and relative playing density in sports such as Australian football, soccer and basketball, no specific suggestions about the influence of manipulating these task constraints in field hockey can be made. It is however suggested that the two manipulations will influence performance variables, activity profiles and positional data in different ways because of their unique interaction with the environment.

4.2 Methods

4.2.1 Participants

Twenty-five skilled junior field hockey players with an average age of 12.2 ± 0.9 years and a standing height of 1.56 ± 0.11 metres volunteered to participate in this study, after ethical approval was granted by the university ethics committee and parental consent was obtained. All children played in a regional team from their city. These teams play in the zone challenges, a competition organised by the State Hockey association for talented club players from the State.

4.2.2 Experimental design

The number of players and playing density was systematically manipulated during field hockey games. Density or the individual playing area per player in m^2 was manipulated by comparing the adult game of hockey ($228m^2$ - labelled standard density) with a half-field game ($158m^2$ – labelled scaled density) commonly used in competition for U10s. The number of players was then co-varied with density with the adult game (11 players a side – labelled standard numbers) compared with 8 players per team (labelled scaled numbers) which is a typical playing number in junior competition (see Table 4.1). Teams completed a 25 minute field hockey match in each condition and there were 11 participants who played in all four game conditions.

Table 4.1. Characteristics of the four different experimental conditions.

	Number of players	Density (m)	Length/Width ratio	Pitch dimensions (m)
Standard density – standard numbers	11 per side	228	± 1.6	91 x 55
Scaled density – standard numbers	11 per side	158	± 1.2	64 x 54
Standard density – scaled numbers	8 per side	228	± 1.6	77 x 47
Scaled density – scaled numbers	8 per side	158	± 1.2	55 x 46

4.2.3 Apparatus and test procedures

All matches were played on a sand-based hockey pitch with a standard field hockey ball and the participants own equipment. After fitting participants with a back vest containing a global positioning system (GPS) unit (Optimeye S5, Catapult Innovations, Melbourne, Australia) sampling at 10Hz, a common 10-minute warm-up was performed. Only one match was played each day with all matches played on the same day of the week one week apart. The games were recorded for analysis with a digital video camera (JVC, model GY-HM100, recording at 25 HZ) positioned on the side of the field and elevated 4m above the pitch. Pre-determined performance variables were quantitatively analysed by the primary researcher using Sportscode (Sportstec Limited, Sydney, Australia).

4.2.4 Dependent variables

Each game was coded and analysed for the following performance variables:

Successful pass:	The successful attempt of a player to deliver the ball to another teammate.
Unsuccessful pass:	The unsuccessful attempt of a player to deliver the ball to another teammate.
Total passes:	The total of attempts of a player to deliver the ball to another teammate.
Successful dribble:	The successful attempt of a player to move while controlling the ball with the stick.
Unsuccessful dribble:	The unsuccessful attempt of a player to move while controlling the ball with the stick.
Total dribbles:	The total of attempts of a player to move while controlling the ball with the stick.
Skilled actions	The sum of total dribbles and total passes.
Successful actions	The sum of successful passes and successful dribbles.
Unsuccessful actions	The sum of unsuccessful passes and unsuccessful dribbles.
High pressure:	The physical pressure applied by a player on an opponent who receives the ball from a teammate within 1 metre of the player.
Medium pressure:	The physical pressure applied by a player on an opponent who receives the ball from a teammate between 1 and 5 metres from the player.
Low pressure:	The physical pressure applied by a player on an opponent who receives the ball from a teammate from more than 5 metres from the player.

Performance variables for each game were indicated as the frequency of the variables per 25-minute playing time, a method previously used by Dellal, et al. (2011) and Klusemann et al. (2012). The primary researcher conducted the coding and intra-rater reliability demonstrated an ICC around the 0.90 for all variables. The activity profiles of the participants, captured by the GPS units, was analysed using Catapult Sprint 5.1 software (Catapult Innovations, Melbourne, Australia). The speed zones for walking (0-3 km/h), jogging (3-8 km/h), running (8-13 km/h), high-speed running (13-18 km/h) and sprinting (>18 km/h) were based on previous research examining the activity profiles of youth players in team sports (See Castagna, D'Ottavio, & Abt, 2003; Castagna, Manzi, Impellizzeri, Weston, & Barbero-Alvarez, 2010).

The positional data from the GPS units of all participants was used to calculate the real density per player. Using Matlab R2014A (MathWorks, Natick, Massachusetts, United States) the GPS coordinates were transformed into X- and Y-coordinates using the bottom left corner of the pitch as the origin (see Figure 4.1). Real density per player was defined as the total space covered by a team divided by the number of field players (Figure 4.1). A convex hull method was used to measure the total space covered by a team (Frencken, Lemmink, Delleman, & Visscher, 2011).

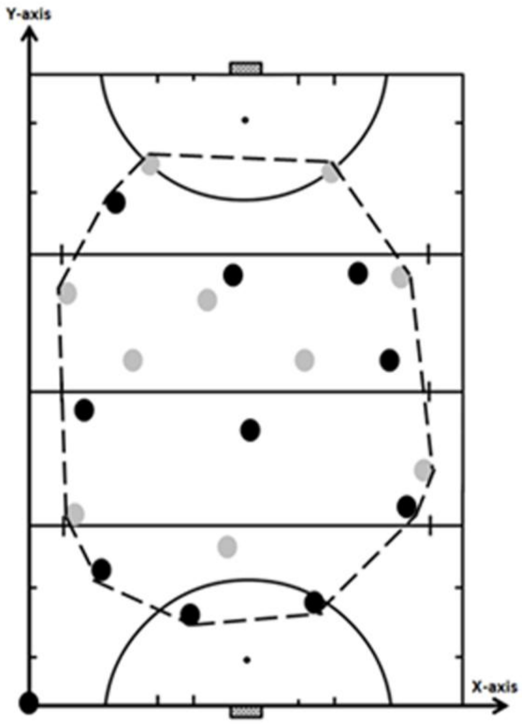

Figure 4.1. Graphical representation of player position and real density (dashed line) measurements of both teams. Coordination of x-axis and y-axis with origins in the left-bottom corner of the pitch.

4.2.5 Data analysis

A two-way analysis of variance (ANOVA) with repeated measures (with number of players and density as within-participant factors) was used to determine the effect of the number of players and density on the performance variables, activity profile and positional data of players. Post hoc comparisons were investigated through the use of *t*-tests with Bonferroni correction. To calculate the effect size, partial eta squared (η_p^2) was used, the descriptive terms were: small effect = 0.01, medium effect = 0.06 and large effect = 0.14 (Cohen, 1988). The raw mean differences and 95% confidence intervals were reported for significant main effects. Statistical significance was set at $p < 0.05$.

4.3 Results

All presented results are based on the performance of the 11 players who performed all four experimental conditions (means, standard deviations, significant main and/or interaction effects can be found in Table 4.2). Only the significant effects are reported for the sake of brevity, the detailed statistical information can be found in Appendix G.

4.3.1 Performance variables

Significant main effects for the lowering of the number of players were found for the following variables: the number of successful passes per player ($F(1.10) = 4.75$, $p = 0.05$, $\eta_p^2 = 0.33$) was increased by 2.68 successful passes per player (95%[0.06, 5.42]). The number of skilled actions per player ($F(1.10) = 7.47$, $p = 0.02$, $\eta_p^2 = 0.43$) was increased by 3.73 skilled actions per player (95%[0.69, 6.77]). The number of successful actions per player ($F(1.10) = 6.83$, $p = 0.03$, $\eta_p^2 = 0.41$) was increased by 3.77 successful actions per player (95%[0.56, 6.99]). The number of high pressure moments per player ($F(1.10) = 8.64$, $p = 0.02$ $\eta_p^2 = 0.46$) was increased by 1.23 high pressure moments per player (95%[0.30, 2.16]). The number of low pressure moments per player ($F(1.10) = 5.17$, $p = 0.05$, $\eta_p^2 = 0.34$) was increased by 1.36 low pressure moments per player (95%[0.03, 2.70]). A significant main effect for the manipulation of the density was found for the following variable: the number of unsuccessful dribbles ($F(1.10) = 5.18$, $p = 0.05$, $\eta_p^2 = 0.34$) was increased by 0.59 unsuccessful dribbles per player (95%[0.01, 1.17]) when the density was scaled to 158m^2. No significant interaction effects were found for the performance variables and therefore, none were reported.

4.3.2 Activity profiles

Significant main effects for scaling the density to 158m^2 were found for the following variables: The distance covered in 13-18 km/h zone ($F(1.10) = 8.15$, $p = 0.02$, $\eta_p^2 = 0.45$) was decreased by 38.0 metres covered in the 13-18 km/h zone (95%[8.34, 67.66]). The distance covered in the >18 km/h zone ($F(1.10) = 9.09$, $p = 0.01$, $\eta_p^2 = 0.48$) was decreased by 21.1 metres covered in the >18 km/h zone

(95%[5.53, 36.83]). The number of players x density interaction was significant for the following variables: the total distance covered in metres ($F(1.10) = 14.17$, $p = 0.00$, $\eta_p^2 = 0.59$) (see Figure 4.2), the distance covered per minute ($F(1.10) = 3.29$, $p = 0.00$, $\eta_p^2 = 0.57$), the distance covered in the 3-8 km/h zone ($F(1.10) = 5.12$, $p = 0.05$, $\eta_p^2 = 0.34$) (see Figure 4.3), the distance covered in the 8-13 km/h zone ($F(1.10) = 12.80$, $p = 0.01$, $\eta_p^2 = 0.56$) (see Figure 4.4) and the distance covered in the 13-18 km/h zone ($F(1.10) = 7.34$, $p = 0.02$, $\eta_p^2 = 0.43$) (see Figure 4.5).

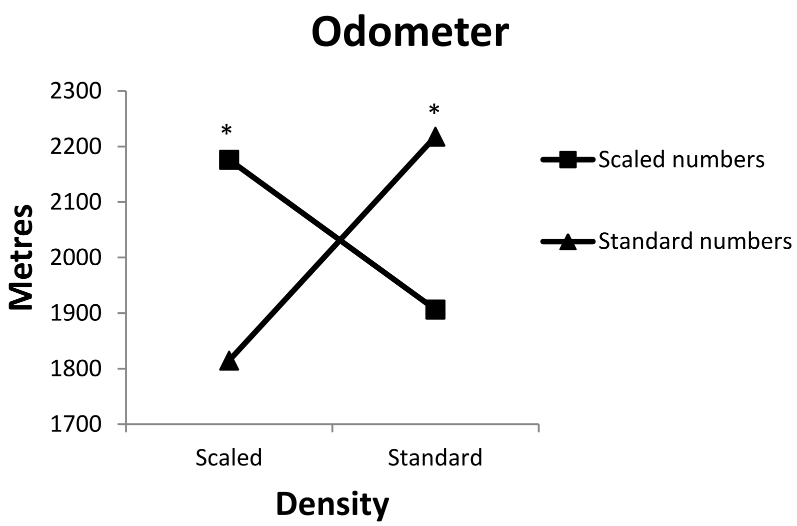

Figure 4.2. Graphical representation of the number of players x density interaction for total distance covered (odometer) in metres. *=significantly different from the scaled density – standard numbers and standard density – scaled numbers conditions

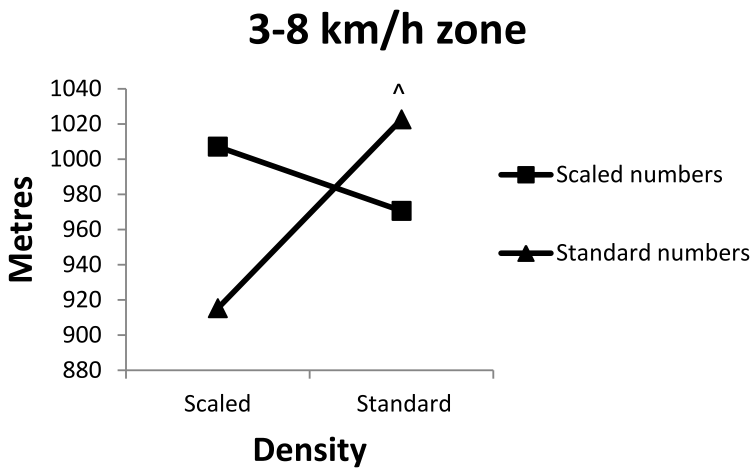

Figure 4.3. Graphical representation of the number of players x density interaction for distance covered in the 3-8 km/h zone. ^ =significantly different from the scaled density – standard numbers condition.

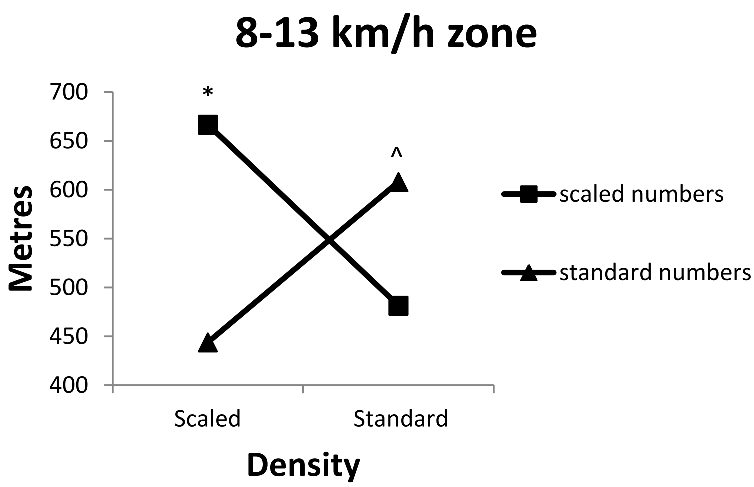

Figure 4.4. Graphical representation of the number of players x density interaction for distance covered in the 8-13 km/h zone. *=significantly different from the scaled density – standard numbers and standard density – scaled numbers conditions and ^ =significantly different from the scaled density – standard numbers condition.

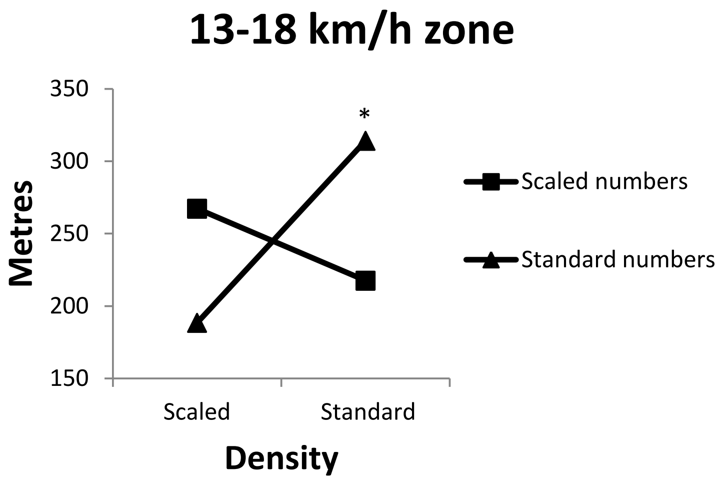

Figure 4.5. Graphical representation of the number of players x density interaction for distance covered in the 13-18 km/h zone. *=significantly different from the scaled density – standard numbers and standard density – scaled numbers conditions.

4.3.3 Positional data

A significant main effect for lowering the number of players was found for the surface area per players ($F(1.11999) = 25524.66$, $p < 0.01$, $\eta_p^2 = 0.68$), indicating that lowering the number of players increased the surface area per player by 19.47m^2 (95%[19.24, 19.71]). A significant main effect of scaling the density to 158m^2 was found for the surface area per players, ($F(1.11999) = 913.95$, $p < 0.01$, $\eta_p^2 = 0.07$), indicating that scaling the density to 158m^2 increased the surface area per player by 3.38m^2 (95%[3.16, 3.60]). Furthermore, the number of players x density interaction revealed a significant effect for the surface area per player ($F(1.11999) = 17971.62$, $p < 0.01$, $\eta_p^2 = 0.60$).

No significant main and/or interaction effects were found for the following variables: the amount of unsuccessful passes, the amount of total passes, the amount of successful dribbles, the amount of long dribbles, the amount of total dribbles, the amount of unsuccessful actions, the amount of medium (1-5m) pressure moments, maximum speed and the distance covered in the 0-3 km/h zone (see Appendix G for full statistical information).

Table 4.2. Mean (±*s*) for all the performance and activity profiles variables in the four different conditions (N=11).

	Standard density (228m²)		Scaled density (158m²)	
	Standard numbers (11 players)	Scaled numbers (8 players)	Standard numbers (11 players)	Scaled numbers (8 players)
Successful pass	6.36 *(±3.5)*	8.55 *(±5.0)*	5.46 *(±3.8)**	8.64 *(±4.9)*
Unsuccessful pass	3.36 *(±1.6)*	2.46 *(±2.2)*	3.18 *(±1.8)*	3.55 *(±1.4)*
Total passes	9.73 *(±4.5)*	11 *(±4.9)*	8.64 *(±5.2)*	12.18 *(±5.3)*
Successful dribble	1.45 *(±1.4)*	2.46 *(±3.0)*	1.45 *(±1.8)*	2.46 *(±2.2)*
Unsuccessful dribble	1.0 *(±1.2)*	0.73 *(±1.1)*	1.1 *(±1.3)*	1.82 *(±1.9)*
Total dribbles	2.46 *(±2.3)*	3.36 *(±3.1)*	2.55 *(±2.5)*	4.27 *(±3.6)*
Skilled actions	12.18 *(±6.3)*	14.36 *(±6.7)*	11.18 *(±6.0)**	16.46 *(±7.2)*
Successful actions	7.82 *(±4.7)*	11.82 *(±7.3)*	6.91 *(±4.3)**	11.09 *(±6.1)*
Unsuccessful actions	4.36 *(±2.2)*	3.18 *(±3.1)*	4.27 *(±2.0)*	5.36 *(±2.7)*
High pressure	1.82 *(±1.7)*	2.64 *(±2.0)*	0.91 *(±1.0)**	2.54 *(±1.8)*
Medium pressure	2.64 *(±2.1)*	3.45 *(±2.9)*	2.91 *(±2.3)*	3.09 *(±2.2)*
Low pressure	1.64 *(±1.7)**	2.18 *(±1.3)*	1.55 *(±2.0)**	3.73 *(±2.6)*
Odometer	2217.9 *(±314.0)*#	1906.4 *(±243.1)*	1814.6 *(±319.8)*	2176.1 *(±335.6)*#
Metres/Min	87.89 *(±12.5)*#	76.37 *(±9.7)*	72.12 *(±12.7)*	86.55 *(±13.3)*#
Maximum speed	20.06 *(±1.4)*	19.76 *(±2.2)*	19.08 *(±1.6)*	19.98 *(±1.5)*
Walking distance (m)	213.4 *(±77.6)*	203.4 *(±53.9)*	247.0 *(±70.6)*	204.6 *(±45.1)*
Jogging distance (m)	1022.6 *(±123.2)* ^	970.6 *(±72.6)*	915.3 *(±123.6)*	1007.1 *(±98.3)*
Running distance (m)	607.8 *(±197.2)*^	481.3 *(±186.5)*	443.8 *(±176.4)*	666.5 *(±249.8)*#
High-speed running distance (m)	314.1 *(±213.3)*#	217.5 *(±90.6)*	188.4 *(±98.8)*	267.2 *(±124.4)*
Sprinting distance (m)	60.0 *(±47.6)*^	33.6 *(±27.1)*	20.2 *(±22.3)*	31.1 *(±19.0)*
Surface area per player (m²)	52.8 *(±11.2)*	46.1 *(±12.8)*	69.0 *(±14.5)*	36.7 *(±9.9)*

Note: * = significantly different from the scaled density – scaled numbers conditions. # = significantly different from scaled density – standard numbers and standard density – scaled numbers conditions. ^ = significantly different from scaled density – standard numbers condition.

4.4 Discussion

The aim of this study was to examine the impact of manipulating the constraints of density and playing numbers on performance variables, activity profiles and positional data in youth field hockey. Results demonstrated that the reduction of the number of players led to an increase in the number of successful passes, skilled actions, successful actions, and high and low pressure moments. Consistent with previous research in basketball and soccer (Klusemann, et al., 2012; Dellal, et al., 2011) playing field hockey with 8 players per side, as opposed to the standard 11 players per side, seems to be beneficial in creating additional opportunities for the execution of key field hockey skills. Such conditions are likely to provide children with more opportunities to attune to key affordances to *freeze* information-movement couplings and create stable movement patterns (Savelsbergh & van der Kamp, 2000). Lowering the number of players also increased the amount of "high pressure" moments. Such pressure moments subsequently resulted in less time for the players to make decisions and perform successful actions (i.e., a dribble or a pass). This time constraint likely forced players to focus on the more specific perceptual information of their teammates and/or opponents in order to guide their movements and perform a successful action (Renshaw, Chow, Davids, & Hammond, 2010). The increase in high pressure moments coupled with the increase in successful actions when playing numbers are reduced, suggests this constraint successfully forces youth players to focus on key information from the environment to guide their movement and positively shape their decision making. A learning environment where children make fewer errors is often associated with an increase in task engagement (e.g., Farrow & Reid, 2010) and an implicit way of learning (Maxwell, Masters, Kerr, & Weedon, 2001) and suggests an avenue for future investigation.

When the individual playing area is reduced, density is increased and vice versa. Results demonstrated an increase in unsuccessful dribbles when density was scaled. This result is consistent with previous research which demonstrated an increase in the amount of dribbles after scaling player density; however, this work didn't distinguish between successful or unsuccessful actions (Casamichana & Castellano, 2010). Interestingly, it seems that density doesn't have a strong influence on the skill performance of participants relative to the number of players. This is likely due to the somewhat artificial nature of the measurement of density which was defined by the relative amount of space available per player. However, this calculation does not consider whether this space is actually used. Comparing the real density per player in the four different playing conditions highlighted that it's not the playing area but the number of players that is most influential. Manipulating the number of players had the biggest influence on the real density per player; lowering the number of players per side increased the real density per player by almost $20m^2$. On the other hand, density manipulation leads to an increase in the real density per player of about $3m^2$. These results are not consistent with previous research in soccer that showed that the real density per players significantly decreased when the playing area was reduced (Silva, et al., 2014). From the results of this study it is clear that it's not the potential available space that dictates the interpersonal distance between players in field hockey; rather it could potentially be the action capabilities of the players that dictate how players interact with each other and their opponents. For example, the maximal passing distance of players could dictate the interpersonal distance between players. A possible explanation for the difference between soccer and field hockey could be due to the fact that the characteristics of the ball in combination with the action capabilities of the players make it easier to use the potential space in soccer than in field hockey. The combination between these constraints also seems to influence the physical demands of youth field hockey players. Scaling the density led to a decrease in high-intensity running (13-18 km/h) and sprinting (>18 km/h), which is consistent with previous research (Casamichana & Castellano, 2010; Davies, et al., 2013). However, both these studies found that the total distance covered was reported to be significantly higher when the individual player area was higher, which was not the case in the current study. Again, the combination between action capabilities and ball characteristics seem to be of influence.

Furthermore, results of the activity profiles show interaction effects for the total distance covered, metres/minute covered, jogging distance (3-8 km/h), running distance (8-13 km/h) as well as for the high-intensity running distance (13-18 km/h). Further exploration of metres/min, which is often used as an indicator of intensity of a training or game (Aughey, 2011), revealed that the highest values were found in the standard numbers – standard density and scaled numbers – scaled density conditions, that represented the full-field game and half-field game. It seems that manipulating the number of players or the density made it easier for players to be able to receive a pass from their teammates, while manipulating both constraints forced the players to be more active in order to be able to receive a pass from their teammates.

In summary, the results provide an insight into the effect of manipulating task constraints in skilled junior field hockey and highlight the important interactive nature of constraints on emergent performance. However, the results also highlight the importance of coaches and practitioners having a clear understanding of the impact of the constraints they choose to manipulate. In particular it is critical to understand how various constraints interact with each other and in turn establish specific information-movement couplings to enhance skill performance and acquisition (Jacobs & Michaels, 2007). Further research should focus on the different manipulation of constraints and its influence on the development of skill acquisition in sports.

Chapter Five

Creating appropriate training environments to improve technical skill, decision-making skill and physical capacity in field hockey

Abstract

The purpose of this study was to determine the influential constraint of small-sided game (SSG) design on the physical, technical and decision-making skills of U14 field hockey players. Thirteen participants played eight different training games where number of players (3 per side or 6 per side) and/or field characteristics (normal game, cage hockey game, possession game and two goals game) was manipulated. Match performance was determined by using notational analysis and physical demands were determined by using GPS analyses. Findings revealed that lowering the number of players increased the number of technical actions performed per player and the physical demands of the SSG. Findings of the field characteristics manipulation revealed that the possession game forced players to control the ball more as a team which resulted in more passes (+4.82 passes) and fewer dribbles (-1.48 dribbles) and tackles (-0.69 tackles) compared to the normal game. The two goals game led to players scoring more goals (+0.61 goals) compared to the normal game while the cage hockey game increased passing (+1.46 passes) and physical demands (+7.32 metres per minute) compared to the normal game. These findings highlight that coaches can promote an emergent change in playing behaviour, and in turn the progressive development of specific skills (i.e., physical , technical or decision making), through the systematic application of specific game constraints used in the training environment. Discussion will focus on the importance of coaches learning to utilise a constraint led approach to game design.

5.1 Introduction

Players of invasion games such as basketball, rugby and soccer, have to possess a multi-dimensional skill-set consisting of great technical sport-specific skills, physical capacities and decision-making skills (Gabbett, Jenkins, & Abertnethy, 2011; Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2014; Ostojic, Mazic, & Dikic, 2006). As such, training activities should be representative of these game dynamics to promote appropriate performance improvement (Pinder, Davids, Renshaw, & Araújo, 2011). To promote appropriate training environments for children, sporting organisations are scaling equipment and field dimensions (Buszard, Reid, Masters, & Farrow, 2016). The scaling and modification of games is one of the fundamentals of the popular teaching paradigm for physical educators to promote understanding and technical proficiency in games; the Teaching Games for Understanding (TGfU) model originally proposed by Bunker and Thorpe (1982) (Memmert et al., 2015). This model aims to help players improve tactical awareness of game play in conjunction with sport-specific skill development through the use of modified games where playing area, rules and equipment are manipulated. To be able to promote specific tactical or technical skill playing behaviour, coaches and physical educators should create appropriate sport-specific learning environments for young players. To create such a learning environment using the TGfU model, coaches and physical educators should understand the effect of manipulating game specifics on playing behaviour (Renshaw et al., 2015).

While the TGfU model provides a framework, a theoretical paradigm is also needed to explain the benefits of using modified games to promote tactical and technical skill learning. The constraints-led approach (Davids, 2010; Davids, Button, & Bennett, 2008) is such a theory and suggests in accordance with Newell (1986) that goal-directed behaviour is the result of the interaction between three types of constraints: environmental, organismic and task constraints. Manipulation or changes in each of these constraints is suggested to influence the outcome of goal-directed behaviour by changing the available perceptual information to create perceptual-movement couplings. To learn new skills, an individual has to actively engage with the environment and get attuned to the perceptual information in the environment to create information-movement couplings (Jacobs & Michaels, 2002). When players get exposed to certain perceptual information more frequently, the couplings become more robust and players are able to use these couplings in new situations and exploit new movement solutions (Savelsbergh & van der Kamp, 2000). Studies into the modification of task constraints in sports show that the manipulation of task constraints can lead to more opportunities for players to get attuned to specific perceptual information. Indeed, studies in basketball and soccer have showed that lowering the number of players led to an increase in the amount of technical actions and passes per player while the physical demands of SSG were similar to those of full-field competition (Klusemann, Pyne, Foster, & Drinkwater, 2012; Owen, Twist, &

Ford, 2004). Similar findings were found in field hockey research where manipulating the number of players led to more technical skill executions while manipulating the personal playing area per player did not affect playing behaviour (Timmerman, Farrow & Savelsbergh, under review). Collectively, these studies have showed that the three constraints interact in a unique way to guide behaviour and that coaches and trainers should be aware of these unique interactions when manipulating constraints to promote a specific behaviour in a sport.

In a playing environment such as a SSG, the interactions between key constraints are constantly changing and as such, players are challenged to perform successful actions in different ways (Davids, Araújo, Vilar, Renshaw, & Pinder, 2013). This search for new movement solutions to meet a performance goal in SSG, referred to as adaptive behaviour, can be promoted by manipulating constraints accordingly (Davids et al., 2013). For example, the effect of manipulating the amount of scoring opportunities in soccer showed that an increase in the number of goal areas led to a larger distance between the centroid of each team and teams playing in a more lateral and defensive way (Travassos, Gonçalves, Marcelino, Monteiro, & Sampaio, 2014). A similar research design was used to examine the effect of scoring mode (line goal, double goal or central goal) on tactical behaviour in soccer (Almeida, Duarte, Volossovitch, & Ferreria, 2016). These studies show that manipulating task constraints can promote a change in behaviour that is beneficial for learning technical skills, decision-making and tactical behaviour. However, task constraints are ideally manipulated in such a way that the perceptual information that is available for players to pick up and inform their decisions and skill executions are still representative of the performance context (Pinder et al., 2011). To create appropriate training environments where children can improve their technical skills as well as decision-making skills, coaches and trainers should understand the interactive nature of constraints and its influence on playing behaviour.

To be able to develop all the necessary skills in field hockey, SSG are suggested as an appropriate training method. SSG can be manipulated in various ways to promote certain goal-directed behaviour. The aim of this study was to examine the influence of manipulating the number of players as well as field characteristic manipulations on players' performance in U14 field hockey. Four SSG were used to examine the influence of different field characteristics: a) normal game, b) cage hockey game (boards on the side-line), c) possession game and d) two goals game (See figure 5.1). The manipulated field characteristics were related to common features of field hockey training or match play. A such, the normal game is representative of a field hockey match, the cage hockey game is related to features of indoor field hockey, often played in the summer period in Australia, the possession game is related to a style of playing which aims to keep ball possession away from the opponent and the two goals game is related to a training game often used in field hockey to increase the number of playing directions. It was hypothesised that (1) a decrease in the number of players would lead to more technical skill actions and an increase in the physical demands (Klusemann et al., 2012; Owen et al., 2004) and that (2) manipulation of the field characteristics will lead to more team-like behaviour in the possession game while it is suggested that the two goals game will increase the amount of goals scored and alter the proportion of lateral and central offensive actions (Almeida et al., 2016; Travassos et al., 2014). Finally it was predicted that the cage hockey game is likely to influence the physical demands experienced as it is suggested that players can transfer the ball quicker around due to the boards on the side-line.

5.2 Methods

5.2.1 Participants

A total of 13 field hockey players with an average age of 13.2 ± 1.1 years and a standing height of 1.59 ± 0.09 metres volunteered to participate in this study, after ethical approval was granted by the university and parental and children consent was obtained. The children had played field hockey for 4.5 ± 2.2 years and competition for 3.9 ± 1.6 years. All the children played in the highest or second highest division of youth competition played in the Melbourne area and trained 2.9 ± 1.9 times a week and played 1.2 ± 0.4 matches per week during the regular hockey season.

5.2.2 Experimental design

To determine the effect of the number of players and different field characteristic manipulations, players attended 12 training sessions. Each training session started with a field hockey specific 10-minute warm-up followed by four SSG. Players performed two SSG with duration of 7.5 minutes per SSG with a 2.5 minutes break between games. The rate of perceived exertion (RPE) was taken two minutes after both SSG were played. After the RPE was taken, a 7.5 minutes break followed and then the same procedure was repeated for the remaining two SSG. All the SSG were played according to the official rules of field hockey with the exceptions that no goalkeepers were present and that the goals were fold-up goals with a width of 1.5 metres and a height of 1 metre (official goal is 3.66 metres wide and 2.14 metres high). No coaches were present to give any typical coaching instruction. Firstly, the number of players per team was manipulated in such a way that players were assigned to a team of 3 players per side (3v3) or to a team of 6 players per side (6v6). To keep the personal playing area per player constant (75 m^2 per player), the 3v3-games were played on a pitch of 28m long and 17m wide and the 6v6-games were played on a pitch of 40m long and 24m wide. The length/width ratio of both pitches corresponded with the length/width ratio of a standard field hockey pitch (L/W ratio of 1.65). The second manipulation focused on the field characteristics of each SSG. Four different small-sided games were designed as detailed below (see Figure 5.1):

1. Normal game (NG): Game with one goal per team and the aim of each team is to score goals.
2. Cage hockey game (CH): Game with one goal per team and indoor hockey boards (height of 10cm) on both side-lines and the aim of each team is to score goals.
3. Possession game (Poss): Game without goals and the aim of each team is to hold possession of the ball for as long as possible.
4. Two goals game (TG): Game with two goals per team and the aim of each team is to score goals.

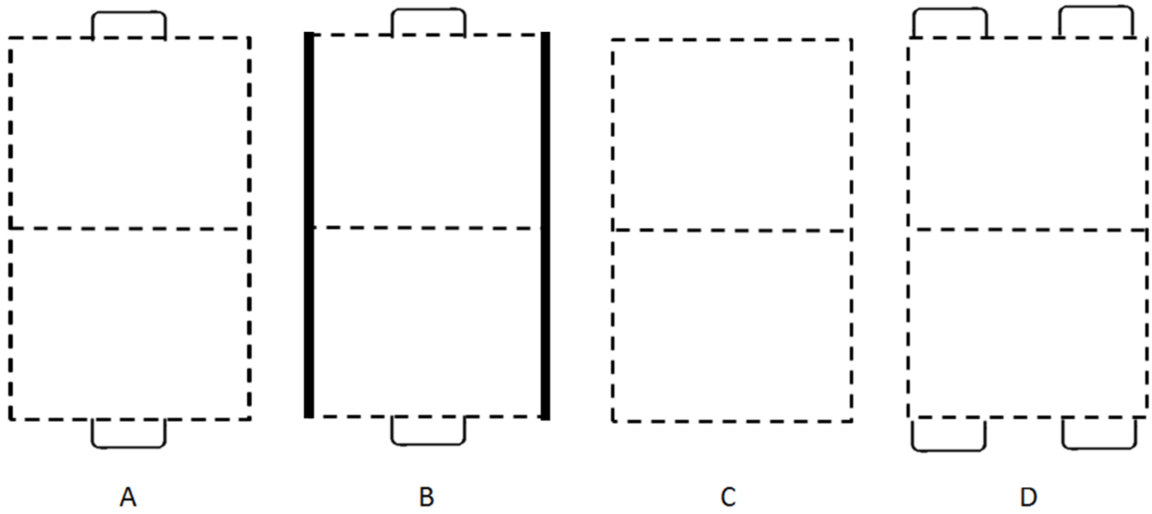

Figure 5.1. Graphical representation of the a) normal game, b) cage hockey game, c) possession game and the d) two goals game.

5.2.3 Test procedure and apparatus

The combination of the two manipulations resulted in eight different SSG. Each training session was devoted to one of the four different SSG mentioned above and two games were played in the 3v3 condition and two games in the 6v6 condition. This led to every single game combination being played three times, with the exception of one Poss-6v6 and one TG-6v6 game session which had to be cancelled. All the players used their own field hockey sticks and all the matches were played on a sand-based hockey pitch using standard field hockey balls (Kookaburra, circumference between 224-235mm and a weight between 156-163grams). Players were asked to wear an Optimeye S5 global positioning system (GPS) unit (Catapult Innovations, Melbourne, Australia) sampling at 10Hz, on their back to measure the physical demands of the different SSG. Digital video cameras (Canon Legria HF-G25, frame rate 25Hz) were positioned on the fence (height: 4m), behind one of the goals of each SSG, to capture all the aspects of the game for post-game notational analysis. A quantitative analysis of field hockey factors was conducted using a notational analysis program (Sportscode, Sportstec Limited, Sydney, Australia), that allowed coding of team and individual characteristics.

5.2.4 Dependent variables

The technical demands of the different SSG were analysed using Sportscode (Sportstec Limited) software, designed for the analysis of sports matches. The following variables were coded:

Successful pass:	Successful attempt of a player to deliver the ball to another teammate.
Unsuccessful pass:	Unsuccessful attempt of a player to deliver the ball to another teammate.
Successful dribble:	Successful attempt of a player to move while controlling the ball with the stick.
Unsuccessful dribble:	Unsuccessful attempt of a player to move while controlling the ball with the stick.
Successful tackle:	Successful attempt of a player to take the ball of an opponent.
Unsuccessful tackle:	Unsuccessful attempt of a player to take the ball of an opponent.
Interception:	Attempt of a player to intercept a pass of an opponent.
Loss of possession:	Loss of the ball by a player due a bad pass or contest.
Goal:	Successful attempt of a player to score a goal.
Scoring opportunity:	Attempt of a player to score a goal.
Low pressure:	Physical pressure applied by a player on an opponent who receives the ball from a teammate from more than 5 metres.
Medium pressure:	Physical pressure applied by a player on an opponent who receives the ball from a teammate between 1 and 5 metres.
High pressure:	Physical pressure applied by a player on an opponent who receives the ball from a teammate within 1 metre.

Technical demands for each SSG were indicated as the frequency of the variables per 10-minute playing time. The primary researcher conducted the coding and intra-rater reliability demonstrated an ICC around the 0.90 for all variables. Conducting a split-time reliability test was not possible as the data of the coding system provided frequencies per playing time of a player. The 10-minutes playing time was chosen as each player participated at least 10-minutes per SSG. The physical demands of the different SSG were analysed using GPS technology. The information of the GPS units was analysed by using Catapult Sprint 5.1 (Catapult Innovations, Melbourne, Australia), a software package specially designed to analyse GPS information. Previous research into the physical demands of youth players proposed the following speed zones: walking (0-3 km/h), jogging (3-8 km/h), running (8-13 km/h), high-speed running (13-18 km/h) and sprinting (>18 km/h) (Castagna, D'Ottavio & Abt, 2003; Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010).

5.2.5 Data analysis

To determine the influence of manipulating the number of players and field characteristics manipulations, the normal game SSG was compared with the three other SSG. A two-way analysis of variance (ANOVA) with repeated measures (with number of players and field characteristics as within-participant factors) was used for each of the 3 comparisons. Results were further investigated through the use of *t*-tests with Bonferroni correction. To calculate the effect size, a partial eta squared (η_p^2) was used with the following norm for effect size: small effect = 0.01, medium effect = 0.06 and large effect = 0.14 (Cohen, 1988). Statistical significance was set at $P < 0.05$.

5.3 Results

Mean and standard deviations of the technical skill data and activity profiles and results of the repeated measures analysis for each comparison are shown in Table 5.1, 5.2 and 5.3 (for detailed statistical information see Appendices J, K and L).

5.3.1 Number of players manipulation

Examining the influence of manipulating the number of players revealed that irrespective of the game played, a significant effect of manipulating the number of players was found and that players always performed more technical actions (passes, dribbles, tackles) when playing with 3 players per side compared to playing with 6 players per side. Any significant number of players by field characteristics interaction effects are detailed in following section. Furthermore, results of the activity profiles revealed that for each SSG comparison, lowering the number of players led to players covering more metres per minute, fewer metres walking, fewer metres jogging, more metres running and more metres high-speed running (see Table 5.1, 5.2 and 5.3). These findings indicate that lowering the number of players increases the physical demands of SSG (Aughey, 2011).

5.3.2 Field characteristic manipulation

5.3.2.1 Normal game and Cage hockey game comparison

Results of the normal game and cage hockey game comparison can be found in Table 5.1. Players performed significantly more unsuccessful passes (+0.63), greater total number of passes (+1.46) and experienced more high pressure moments (+0.49) in the cage hockey game compared to the normal game. The cage hockey game also led to players covering more metres per minute (+7.32) compared to the normal game.

Findings also revealed a significant number of players by field characteristics interaction for the high pressure moments ($F(1.12) = 5.2$, $p = 0.042$, $\eta_p^2 = 0.30$), indicating that lowering the number of players in the normal game resulted in fewer high pressure moments while lowering the number of players in the cage hockey game resulted in more high pressure moments.

Table 5.1. Mean and standard deviations of technical skills data and activity profiles of the normal and cage hockey game (N=13). PL = number of players manipulations, SSG = field characteristics manipulation and INT = interaction effect.

	Normal game		Cage Hockey		Significant effects (p<0.05)
	3v3	6v6	3v3	6v6	
Successful passes	8.10 (3.17)	5.14 (2.27)	8.83 (4.00)	6.06 (2.46)	PL
Unsuccessful passes	2.65 (0.51)	1.64 (0.88)	3.40 (1.11)	2.15 (0.82)	PL and SSG
Total passes	10.75 (3.13)	6.78 (2.90)	12.24 (4.52)	8.21 (2.83)	PL and SSG
% Successful passes	73.02 (11.74)	77.03 (10.87)	69.88 (9.80)	72.14 (11.39)	
Successful dribbles	2.81 (1.62)	1.15 (0.83)	2.66 (1.50)	1.39 (1.07)	PL
Unsuccessful dribbles	1.61 (1.09)	0.78 (0.89)	1.53 (0.93)	0.76 (0.59)	PL
Total dribbles	4.42 (2.27)	1.92 (1.31)	4.19 (2.07)	2.15 (1.41)	PL
% Successful dribbles	64.89 (18.83)	56.42 (28.49)	60.01 (18.38)	54.70 (29.54)	
Successful tackles	1.57 (1.11)	0.81 (0.52)	1.47 (0.80)	1.14 (0.96)	
Unsuccessful tackles	0.47 (0.36)	0.29 (0.28)	0.68 (0.61)	0.60 (0.33)	
Total tackles	2.04 (1.31)	1.10 (0.61)	2.15 (1.11)	1.75 (1.04)	
% Successful tackles	73.92 (20.36)	67.63 (28.94)	69.33 (20.51)	61.45 (27.28)	
Interceptions	2.23 (1.36)	1.62 (1.22)	2.36 (1.20)	2.25 (1.34)	
Loss of ball possession	1.97 (0.70)	1.17 (0.93)	1.87 (1.29)	1.40 (0.95)	PL
Low pressure	1.36 (0.64)	0.55 (0.36)	1.72 (0.81)	0.38 (0.37)	PL
Medium pressure	4.65 (0.74)	3.50 (1.14)	5.12 (1.81)	3.86 (0.94)	PL
High pressure	0.69 (0.46)	0.78 (0.65)	1.65 (0.93)	0.78 (0.57)	PL, SSG and INT
Goals	1.12 (0.61)	0.42 (0.43)	1.35 (0.93)	0.38 (0.56)	PL
Scorings opportunity	0.90 (0.47)	0.30 (0.45)	1.05 (0.99)	0.41 (0.59)	PL
Metres/Min	75.1 (8.8)	65.9 (11.8)	80.5 (13.2)	75.1 (15.1)	PL and SSG
% Walking (0-3 km/h)	13.4 (4.5)	17.8 (6.7)	14.8 (5.8)	17.7 (7.8)	PL
% Jogging (3-8 km/h)	50.1 (4.5)	54.4 (6.0)	49.4 (3.9)	52.5 (6.5)	PL
% Running (8-13 km/h)	25.5 (3.8)	20.8 (4.4)	26.3 (5.0)	22.2 (5.1)	PL
% High-speed running (13-18 km/h)	9.9 (3.0)	6.5 (3.1)	8.8 (3.2)	6.9 (3.1)	PL
% Sprinting (>18 km/h)	1.0 (1.1)	0.6 (0.7)	0.8 (1.0)	0.7 (1.1)	
RPE	4.8 (0.8)	5.4 (1.1)	5.1 (0.8)	5.3 (1.0)	

5.3.2.2 Normal game and Possession game comparison

Results of the normal game and possession game comparison can be found in Table 5.2. Players performed significantly more successful passes (+3.48), more unsuccessful passes (+1.35), greater total number of passes (+4.82), fewer successful dribbles (-0.65), fewer unsuccessful dribbles (-0.83), smaller total number of dribbles (-1.48), fewer successful tackles (-0.57), smaller total number of tackles (-0.69), more medium pressure (+2.12) and more high pressure (+0.84) in the possession game compared to the normal game. The possession game also led to players covering more metres per minute (+9.82), fewer metres of high-speed running (-2.50) and fewer metres of sprinting (-0.52) compared to the normal game.

Findings also revealed a significant number of players by field characteristics interaction for the number of unsuccessful passes ($F(1.12) = 6.2$, $p = 0.028$, $\eta_p^2 = 0.34$), total passes ($F(1.12) = 5.6$, $p = 0.036$, $\eta_p^2 = 0.32$), total dribbles ($F(1.12) = 5.2$, $p = 0.041$, $\eta_p^2 = 0.30$) and low ($F(1.12) = 5.5$, $p = 0.037$, $\eta_p^2 = 0.31$), medium ($F_1(1.12) = 7.7$, $p = 0.017$, $\eta_p^2 = 0.39$) and high pressure ($F(1.12) = 13.8$, $p = 0.003$, $\eta_p^2 = 0.54$) moments and high-speed running ($F(1.12) = 9.1$, $p = 0.011$, $\eta_p^2 = 0.43$) and RPE ($F(1.12) = 7.3$, p=0.019, $\eta_p^2 = 0.38$). The most profound significant effects are discussed in more detail below. For the number of unsuccessful and total passes this significant interaction indicated that despite the main effect of lowering the number of players, players performed more passes in the 6v6 possession game compared to the 3v3 normal game. For the high pressure moment this interaction effect indicated that lowering the number of players in the normal game resulted in a decrease in high pressure moments while lowering the number of players in the possession game led to an increase of high pressure moments. For high-speed running this interaction effect indicated that lowering the number of players in the normal game led to an increase in high-speed running while lowering the number of players did not affect high-speed running in the possession game.

Table 5.2. Mean and standard deviations of technical skills data and activity profiles of the normal and possession game (N=13). PL = number of players manipulations, SSG = field characteristics manipulation and INT = interaction effect.

	Normal game		Possession		Significant effects (p<0.05)
	3v3	6v6	3v3	6v6	
Successful passes	8.10 (3.17)	5.14 (2.27)	12.36 (3.15)	7.83 (3.70)	PL and SSG
Unsuccessful passes	2.65 (0.51)	1.64 (0.88)	4.52 (0.97)	2.46 (0.90)	PL, SSG and INT
Total passes	10.75 (3.13)	6.78 (2.90)	16.88 (2.89)	10.29 (3.75)	PL, SSG and INT
% Successful passes	73.02 (11.74)	77.03 (10.87)	72.37 (7.90)	73.96 (12.28)	
Successful dribbles	2.81 (1.62)	1.15 (0.83)	1.73 (1.08)	0.93 (0.87)	PL and SSG
Unsuccessful dribbles	1.61 (1.09)	0.78 (0.89)	0.53 (0.68)	0.19 (0.38)	PL and SSG
Total dribbles	4.42 (2.27)	1.92 (1.31)	2.26 (1.57)	1.12 (0.99)	PL, SSG and INT
% Successful dribbles	64.89 (18.83)	56.42 (28.49)	72.24 (29.53)	72.66 (37.57)	
Successful tackles	1.57 (1.11)	0.81 (0.52)	0.90 (0.68)	0.34 (0.50)	PL and SSG
Unsuccessful tackles	0.47 (0.36)	0.29 (0.28)	0.28 (0.34)	0.25 (0.37)	
Total tackles	2.04 (1.31)	1.10 (0.61)	1.18 (0.70)	0.59 (0.68)	PL and SSG
% Successful tackles	73.92 (20.36)	67.63 (28.94)	68.76 (31.27)	35.54 (44.60)	PL
Interceptions	2.23 (1.36)	1.62 (1.22)	2.86 (1.66)	1.98 (1.35)	PL
Loss of ball possession	1.97 (0.70)	1.17 (0.93)	1.92 (0.83)	1.25 (0.80)	PL
Low pressure	1.36 (0.64)	0.55 (0.36)	1.98 (1.02)	0.38 (0.57)	PL and INT
Medium pressure	4.65 (0.74)	3.50 (1.14)	7.75 (1.75)	4.64 (2.44)	PL, SSG and INT
High pressure	0.69 (0.46)	0.78 (0.65)	2.02 (0.85)	1.11 (0.61)	PL, SSG and INT
Metres/Min	75.1 (8.8)	65.9 (11.8)	83.5 (7.5)	77.2 (15.1)	PL and SSG
% Walking (0-3 km/h)	13.4 (4.5)	17.8 (6.7)	14.3 (5.5)	17.1 (7.8)	PL
% Jogging (3-8 km/h)	50.1 (4.5)	54.4 (6.0)	51.6 (5.4)	54.5 (4.5)	PL
% Running (8-13 km/h)	25.5 (3.8)	20.8 (4.4)	27.8 (3.9)	22.7 (7.3)	PL
% High-speed running (13-18 km/h)	9.9 (3.0)	6.5 (3.1)	6.0 (3.4)	5.4 (2.9)	PL, SSG and INT
% Sprinting (>18 km/h)	1.0 (1.1)	0.6 (0.7)	0.3 (0.5)	0.3 (0.6)	SSG
RPE	4.8 (0.8)	5.4 (1.1)	5.4 (1.3)	5.0 (0.8)	INT

5.3.2.3 Normal game and Two goals game comparison

Results of the normal game and two goals game comparison can be found in Table 5.3. Players scored significantly more goals (+0.61) in the two goals game compared to the normal game. The two goals game also led to players covering more metres per minute (+11.21) and more metres of running (+1.85) compared to the normal game.

Findings also revealed significant number of players by field characteristics interaction effect for number of goals scored (F(1.12) = 6.3, p = 0.028, η_p^2 = 0.34), high-speed running (F(1.12) = 6.5, p =

0.025, $\eta_p^2 = 0.35$) and RPE ($F(1.12) = 6.9$, $p = 0.022$, $\eta_p^2 = 0.36$). The most profound significant effects are discussed in more detail below. For high-speed running this interaction effect indicated that lowering the number of players in the normal game led to an increase in high-speed running while lowering the number of players did not affect high-speed running in the two goals game. For RPE this interaction effect indicated that lowering the number of players in the normal game resulted in a decrease in RPE while lowering the number of players in the two goals game resulted in an increase in RPE.

Table 5.3. Mean and standard deviations of technical skills data and activity profiles of the normal and two goals game (N=13). PL = number of players manipulations, SSG = field characteristics manipulation and INT = interaction effect

	Normal game		Two goals		Significant effects (p<0.05)
	3v3	6v6	3v3	6v6	
Successful passes	8.10 (3.17)	5.14 (2.27)	8.70 (3.08)	5.62 (2.38)	PL
Unsuccessful passes	2.65 (0.51)	1.64 (0.88)	2.66 (1.07)	1.91 (1.19)	PL
Total passes	10.75 (3.13)	6.78 (2.90)	11.35 (3.30)	7.53 (1.99)	PL
% Successful passes	73.02 (11.74)	77.03 (10.87)	75.43 (10.99)	71.75 (18.58)	
Successful dribbles	2.81 (1.62)	1.15 (0.83)	3.46 (1.94)	1.54 (1.26)	PL
Unsuccessful dribbles	1.61 (1.09)	0.78 (0.89)	1.41 (1.23)	0.74 (0.85)	PL
Total dribbles	4.42 (2.27)	1.92 (1.31)	4.87 (2.49)	2.29 (1.69)	PL
% Successful dribbles	64.89 (18.83)	56.42 (28.49)	72.54 (23.60)	63.20 (27.32)	
Successful tackles	1.57 (1.11)	0.81 (0.52)	1.27 (0.67)	0.82 (0.79)	PL
Unsuccessful tackles	0.47 (0.36)	0.29 (0.28)	0.64 (0.51)	0.24 (0.30)	PL
Total tackles	2.04 (1.31)	1.10 (0.61)	1.91 (0.82)	1.06 (0.72)	PL
% Successful tackles	73.92 (20.36)	67.63 (28.94)	67.34 (27.39)	64.30 (41.96)	
Interceptions	2.23 (1.36)	1.62 (1.22)	2.45 (1.33)	1.99 (1.07)	
Loss of ball possession	1.97 (0.70)	1.17 (0.93)	1.77 (0.98)	1.26 (0.88)	PL
Low pressure	1.36 (0.64)	0.55 (0.36)	1.10 (0.45)	0.99 (0.67)	PL
Medium pressure	4.65 (0.74)	3.50 (1.14)	5.30 (1.92)	3.49 (1.49)	PL
High pressure	0.69 (0.46)	0.78 (0.65)	1.05 (0.60)	0.91 (0.77)	
Goals	1.12 (0.61)	0.42 (0.43)	2.20 (1.51)	0.57 (0.53)	PL, SSG and INT
Scorings opportunity	0.90 (0.47)	0.30 (0.45)	1.25 (1.24)	0.15 (0.27)	PL
Metres/Min	75.1 (8.8)	65.9 (11.8)	87.43 (9.9)	76.0 (11.9)	PL and SSG
% Walking (0-3 km/h)	13.4 (4.5)	17.8 (6.7)	13.5 (4.9)	15.6 (5.9)	PL
% Jogging (3-8 km/h)	50.1 (4.5)	54.4 (6.0)	50.8 (4.4)	52.9 (5.5)	PL
% Running (8-13 km/h)	25.5 (3.8)	20.8 (4.4)	27.3 (4.6)	22.7 (4.8)	PL and SSG
% High-speed running (13-18 km/h)	9.9 (3.0)	6.5 (3.1)	7.9 (2.5)	7.8 (3.1)	PL and INT
% Sprinting (>18 km/h)	1.0 (1.1)	0.6 (0.7)	0.5 (0.5)	1.0 (1.2)	
RPE	4.8 (0.8)	5.4 (1.1)	5.2 (0.9)	4.8 (0.6)	INT

5.4 Discussion

The aim of this study was to examine the influence of manipulating the number of players as well as field characteristics on players' performance in U14 match play. As expected the manipulation of various key constraints led to a range of significant differences in the manner in which the various SSG were played. As anticipated, each field characteristic manipulation had a significant impact on the way that game was played. For example, removing the goal in the possession game led to players performing more passes, fewer dribbles and tackles under higher time constraints. Similarly, adding an additional set of goals in the two goals game led to more goals being scored under higher physical demands while placing boards on the side-line in the cage hockey game increased the intensity of the game as there were more passes and high pressure moments leading to more unsuccessful passes.

A key finding was that lowering the number of players in each of the SSG (i.e., 3v3 rather than 6v6) led to an increase in the number of technical actions each player performed in a given game. This general manipulation seems to be a powerful effect that can provide children more opportunities to practice these skills under game-specific constraints, which is beneficial for skill development and decision-making (Davids, Araújo, Correia, & Vilar, 2013). Although an increase in technical actions can also be achieved through the use of stereotypical drills, it is argued that game-based training activities show greater long-term skill improvement than drill practice (Farrow, Pyne, & Gabbett, 2008; Gabbett, Jenkins, & Abernethy, 2009). A further benefit of game-based activities is the development of decision-making skills. For example, retrospective training data of elite Australian football players showed that expert decision-makers had participated in more game-based training than non-experts (Berry, Abernethy, & Coté, 2008).

The most prominent result of the field characteristic manipulations showed that playing the possession game changes the decision-making process of the players through a type a playing style where players are forced to connect more with each other and move more into free space to receive a pass. Removal of the goal forces players to focus on different perceptual information from the environment to guide their behaviour, which is linked with a change in technical execution. One of the aims of TGfU is that coaches and physical educators manipulate SSG in such a way that training environments are representative of game dynamics to facilitate the development of appropriate technical and decision-making skills (Pinder et al., 2011). Furthermore, it is suggested that minimal instructions are provided during a training session as instructions can influence the decision-making process of players and act as a (negative) constraint on players (Cordovil et al., 2009). No instructions were provided before and after the games in the current study and it can be assumed that the emergent behaviour in the different SSG is solely promoted by the manipulated task constraints in interaction with the action capabilities of the players (Newell, 1986). Players are therefore able to learn to make decisions that fit their action capabilities in an environment that is representative of game-specifics, which is argued to more appropriately develop their skills for a full field game. These findings highlight a key tenet of the constraints-led approach that through thoughtful manipulation of key constraints emergent playing behaviour can occur in an expected manner.

Findings of the normal game and possession game comparison revealed that the removal of the goal promotes a playing style where players try to connect more with each other and therefore players tend to perform more passes and fewer dribbles and tackles. It should be noted that the number of tackles are strongly correlated with the number of dribbles as a player can only perform a tackle when their opponent is dribbling with the ball. The temporal demands of the possession game are higher than the normal game and it’s argued this causes a decrease in decision time and forces players to focus on more specific perceptual information to guide their decisions (Jacobs & Michaels, 2002). The increase in high pressure moments coupled with a similar successful rate in execution when playing the possession game, suggests that this constraint successfully forces players to focus on key information and positively shape their decision making (Renshaw, Chow, Davids, & Hammond, 2010). When comparing the physical demands of both SSG, it is clear from the metres per minute measure that the possession game is more physically demanding (Aughey, 2011). However, players covered lower percentages in high-speed running and sprinting in the possession game. It is suggested that the increase in passing opportunities that emerges by playing a possession game has the potential to lead to a greater improvement of passing abilities which has been shown to be a discriminating factor between talented and non-talented field hockey players (Nieuwenhuis, Spamer, & van Rossum, 2002).

Results of the cage hockey and normal game comparison showed that the cage hockey game led to more passes and high pressure moments. Similar to the possession game, the increased temporal demands, due to an increase in number of high pressure moments, did not influence the quality of technical skill execution. The cage hockey game also led to a more physically demanding game and this is likely to improve the endurance levels of field hockey players, which again has been shown to be a discriminating factor between talented and non-talented players (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Nieuwenhuis et al., 2002).

The comparison between the normal and the two goals game revealed that the two goals game led to an increase in number of goals scored as well as an increase in metres covered per minute and metres run. Although the two goals game did not affect the number of technical actions, it could be argued that the number of goals influenced the tactical team-behaviour (Travassos et al., 2014). Increasing the number of goals in soccer resulted in teams spending more time in the side corridors of the pitch which indicated that players used a bigger proportion of the pitch to create an offensive action. It is therefore suggested that coaches can manipulate the number of goals to force players to broaden their visual perspective and force them to attune to different perceptual information (Davids et al., 2013). Further research should incorporate more sensitive measurements of tactical team-behaviour to determine the specific influence of task manipulations on tactical team-behaviour in field hockey which was beyond the scope of the current study. Similar to the cage hockey game, the two goals game led to a more physically demanding game compared to the normal game which might suggest that players will improve their endurance capacity by playing the two goals game.

From a more applied perspective, results of the current study indicate that manipulating different constraints of a SSG can create learning environments where players can develop specific field hockey skills. When coaches aim to improve the passing abilities of players, they are advised to use the possession game. The possession game can also be used to improve the players' decision-making skills due to the increase in temporal demands. Coaches can regulate the physical demands of this SSG by manipulating the number of players; fewer players per team will lead to a more physically demanding game. To improve goal scoring skills, it is suggested to play the two goals game. When classifying the normal game as the standard complexity of the game, it can be argued that the two goals game is more complex as the physical demands are higher. Furthermore, the cage hockey game can be seen as more complex than the normal game as it is more physically and temporal demanding. Finally, the possession game can be seen as the most complex game due to the combination of temporal and physical demands with a significant increase in passing actions.

Table 5.4. Comparison between the normal game and manipulated SSG.

	Technical demands	Physiological demands	Decision-making demands
Cage hockey game.	Influences technical demands by manipulating number of players.	Improves physiological skills of players.	Improves DM-skill due to an increase in temporal and physiological demands.
Possession game	Improves passing skills due to increase in passing frequencies.	Influences physiological demands by manipulating number of players.	Improves DM-skills due to an increase in temporal and physiological demands.
Two goals game	Improves scoring skills due to increase in scoring frequencies.	Influences physiological demands by manipulating number of players.	Suggested to improve DM-skill due to an increase of playing directions.

In conclusion, coaches and trainers are able to use SSG to create an appropriate training environment to develop all necessary skills for field hockey. Lowering the number of players will lead to more technical actions performed per player and a more physically demanding game. Manipulating specific field characteristics will force players to focus on different perceptual information which influences the technical skill, decision-making as well as the physical demands of the game. Future research should focus on the development of technical and decision-making skills after a SSG training program.

Chapter Six

General Discussion

6.1 Introduction

This thesis aimed to address two questions: (1) evaluate what performance characteristics distinguish between skill levels at different stages of development (age) by using a multi-dimensional objective approach to performance testing in field hockey, and (2) gain a more complete understanding of the influence of competition and training environments on the emergence of critical field hockey skills (as identified in the first thesis aim). In this chapter, the overall findings of each experiment will be summarised and the theoretical and practical implications of these experiments discussed. Furthermore, the strengths and limitations of this thesis will be evaluated and suggestions for future research provided.

6.2 Findings of experimental series

6.2.1 Talent selection in field hockey

The experiment conducted in Chapter 3 explored what kind of performance characteristics differentiated between selected and non-selected state level players in Australian field hockey with the use of a holistic testing battery. Specifically, the most prominent differences between players selected for a state team and those that were not were dribbling skills and the ability to pass or hit the ball accurately and quickly to a target. In addition to the sport-specific technical skills, state level field hockey players outperformed their club level peers on speed and endurance capacities. State level males scored significantly better on the sprint test (5m sprint test) and the multistage shuttle run test and state level females scored significantly better on agility and the multistage shuttle run test compared to their club level counterparts. The importance of these physical capacities are reflected in the differences in physical demands between national and international level competition levels (Jennings, Cormack, Coutts, & Aughey, 2012a) and in previous research (Keogh, Weber & Dalton, 2003; Nieuwenhuis, Spamer & van Rossum, 2002), that has also demonstrated that elite field hockey players scored better on endurance and speed tests (40m sprint test). In contrast, Elferink-Gemser, Visscher, Lemmink, and Mulder (2004) reported that elite players scored significantly better solely on a sprint test (30m shuttle sprint).

In addition to the tests used in previous research a perceptual-cognitive skill test and self-regulation skill measurement were included. The results of the decision-making test revealed that male state level players scored significantly higher than club level players while no significant difference was found between the female players. However, large differences in decision-making performance were found between female players of the U13 and U15 groups but this trend disappeared in the U18 group. The results of the self-regulation questionnaire revealed that, in contrast to previous research, no differences in self-regulatory skills were found between state and club level players (Jonker, Elferink-Gemser, & Visscher, 2010; Toering, Elferink-Gemser, Jordet, & Visscher, 2009). This could suggest that Australian expert selectors and coaches don't consider self-regulation as an important skill to possess to compete at a high level of competition, however, analysis of the self-regulation scores more closely, revealed that there is a gradual increase in self-regulatory skill differences between male state and club level players as age increased. This might indicate that self-regulation is not considered as a criterion of selection in the U13 and U15 group but is for selection in the U18 state team, which is in line with evidence suggesting that self-regulatory skills are typically developed between the ages of 12-16 years (Jonker, Elferink-Gemser, Tromp, Baker, & Visscher, 2015). Furthermore, the results of chapter 3 could also indicate that self-regulation is indeed an important skill to possess but that all the participants already possessed this skill during the testing as all players performed at a reasonable performance level.

Based on the findings of Chapter 3, it can be concluded that experienced selectors and coaches perceive dribbling skills, passing/hitting skills and speed and endurance capacities as the most important skills to possess to be selected into a representative state team. However, this study also highlighted that the relative importance of different performance characteristics can change during the development years of players and that several gender differences are apparent; indicating that the selection for representative state teams at different ages and for different sexes is sometimes based on different performance characteristics (Elferink-Gemser & Visscher, 2012). Furthermore it was apparent that several of these performance characteristics are highly influenced by maturational status and training history. Consistent with previous research maturational status strongly influenced the physical capacities of 11-16 year old athletes (Pearson, Naughton, & Torode, 2006). Indeed, it was shown that state level players had their PHV at an earlier age compared to club level players, which could indicate that state level players possess these advantageous speed and endurance capacities due being early matured instead of being more 'talented'. Further a positive relationship was found between the amount of training and sporting success, which could suggest that the superior technical skills, decision-making skills and physical capacity of state level players is the result of the players' training history. In the current study, state level players reported that they engaged in field hockey at a younger age then club level players and significant differences in the invested hours in field hockey training per year were apparent from the age of 10 years. Interestingly, selection for state teams in Australia start at the age of 11 years old, thus state level players seem to have accumulated more training hours before selection for state teams. This could imply that state level players are selected based on superior technical, decision-making and physical skills, which are the result of more training and not necessarily the result of players being more 'talented'. It is argued that talent identification should aim to identify players that would benefit most from a systematic training program and not focus solely on current performance (Williams & Reilly, 2000).

The results of Chapter 3 could suggest that coaches and trainers should focus on developing the skills of young field hockey players that are deemed to be of importance for selection into a representative state teams. However, it is unclear from the study conducted in Chapter 3 if the performance characteristics that distinguish between state and club level players translate to future sporting success (Abbott, Button, Pepping, & Collins, 2005). Furthermore, the findings of this study emphasised that the interaction between personal, environmental, practice and training characteristics dictate how 'talented' an athlete is and therefore influences the selection into a representative squad (Rees et al., 2016). For example, the practice history data revealed that state level players had already accumulated significantly more hours of field hockey training (training constraint) before being selected. It is suggested that the environment where they grew up (field hockey club, private school or family members) (environmental constraint) facilitated more hours of training and that led to an increase in field hockey skills (personal constraint) and ultimately being selected for a representative state team.

6.2.2 Skill acquisition in field hockey

Chapter 4 explored the influence of changing task constraints in competition structures. From the sport history data and anecdotal evidence, young field hockey players typically engage in one training session and one competition match per week, which emphasises the importance of not only appropriate training environments but also competition environments. Therefore, Chapter 4 examined the influence of manipulating the number of players and personal playing area on emergent match performance. One of the main contributions of this study was that it included the adult constraints as a playing condition and compared them with the playing behaviour of young field hockey players in modified playing conditions. Match performance of each individual player was analysed for technical, decision-making and physical demands.

Results demonstrated that lowering the number of players caused players to perform more successful passes, more short dribbles, more skilled actions, more successful actions and experienced more high and low pressure moments. The findings suggest it would also be beneficial for the acquisition of field hockey skills as children have more opportunities to attune to affordances to freeze information-movement couplings and in turn to create stable movement patterns (Jacobs & Michaels, 2002). Furthermore, lowering the number of players also increased the amount of high pressure moments which resulted in less time for players to make decisions and to perform successful actions. This time constraint, in combination with the concomitant increase in successful actions, may have been due to the players being forced to focus on more specific perceptual information within the environment to guide their movements and positively influence their decision-making (Renshaw, Chow, Davids, & Hammond, 2010). It can be concluded that U12 field hockey players would benefit from playing on a half-field pitch with 8 players per side as this provides a better performance environment for children.

Another factor that was manipulated was the personal playing area per player (density). Results indicated that manipulating the density on the field hockey pitch only resulted in an increase in the number of unsuccessful dribbles. The results of this study are inconsistent with findings in Australian football and soccer (Davies, Young, Farrow, & Bahnert, 2013; Casamichana & Castellano, 2010) and it suggested that playing behaviour is influenced by the interaction between action capabilities of players (organismic constraint) and ball characteristics (task constraint). It is therefore suggested that appropriate competition structures are created with a consideration for the action capabilities of players, as this will influence how players interact with task and environmental constraints (Newell, 1986). The need to scale competition structure for different age groups is also highlighted in a review by Buszard, Reid, Masters and Farrow (2016) who reported that guidelines for junior playing areas are not in line with the growth curve of young children.

It can be concluded that this study adds to the body of literature on the constraints-led approach by highlighting the dynamic nature of skilled performance and the need to consider the influence of all three types of constraints when manipulating game constraints to promote skill and ultimately talent development. It extends this body of work by comparing playing behaviour of young field hockey players in modified playing conditions in addition to an adult constrained playing condition.

Chapter 5 explored the influence of manipulating task constraints in order to create appropriate training environments for young field hockey players. Specifically, the influence of manipulating the number of players and the field characteristics of small-sided games (SSG) was determined and discussed with its implication on developing technical, decision-making and physical skills that are necessary in field hockey. Results demonstrated that when playing field hockey with 3 players per team compared to 6 players per team, players perform significantly more passes, more dribbles, more tackles, score more goals and cover more metres per minute. Due to an increase in the number of technical actions performed per player, athletes are able to create more robust information-movement couplings (Davids, Araújo, Correia, & Vilar, 2013). The benefit of learning technical actions in SSG compared to drills is that children are able to become attuned to specific perceptual information that is representative of the match context (Pinder, Davids, Renshaw, & Araújo, 2011). Furthermore, game-based activities have been shown to increase the number of decision-making opportunities and cognitive demands compared to closed drills in Australian football and in turn, this increase in cognitive demands in SSG is associated with greater skill learning (Farrow, Pyne, & Gabett, 2008; Lee, Swinnen, & Serrien, 1994).

The most prominent finding of manipulating the field characteristics of SSG in field hockey was that the removal of the goal forced players to control the ball more collectively as a team, rather than as an individual, which resulted in players performing more passes and less dribbles, and less tackles compared to the normal game. In conjunction with an increase in the number of passes, players had to perform their passes under greater time constraints. Similar to findings in Chapter 4, this time constraint did not influence the execution of passes as the percentage of successful passes remained the same and likely forced players to focus on more specific information from the environment to guide their decision-making (Renshaw et al., 2010).

The effect of task constraints on the physical demands of SSG revealed that lowering the number of players increased the intensity of the game as players covered more distance per minute (Aughey, 2011). Manipulating field characteristics of SSG demonstrated that the cage hockey, possession and two goals games were more physically demanding than the normal game. It is argued that the constraints of the cage hockey and the two goals game allowed players to use a bigger proportion of the pitch while the possession game forced players to be more active to receive the ball from teammates. It is suggested that this increase in physical demands is likely to improve the endurance capacity of players, which has shown to be a discriminating factor between talented and non-talented players (Elferink-Gemser et al., 2004; Nieuwenhuis et al., 2002).

It can be concluded that this study adds to the literature on the constraints-led approach by integrating the effect of manipulating task constraints on technical skill, decision-making, as well as physical demands in youth field hockey. This study also highlighted that a change in playing behaviour can be solely promoted by manipulating task constraints without the need of verbal instructions as goal-directed behaviour is the result of the interaction between organismic, task and environmental constraints (Newell, 1986). Furthermore, it is argued that coaches and physical educators can create a learning environment where players can develop specific field hockey skills. For example, it is suggested that the removal of the goal will force players to show more collective team behaviour while the cage hockey and two goals game have their own unique influence on playing behaviour and in turn the development of critical field hockey skills.

6.2.3 General discussion

The overall aim of this thesis was to gain insight into what performance characteristics distinguish between skill levels at different stages of development and to gain more understanding of how these critical field hockey skills emerge in competition and training environments. The first study revealed that the chance of being selected into a representative team is highly dynamic in nature as this is due to the interaction between organismic, task and environmental constraints (Davids, Button, & Bennett, 2008). This dynamic aspect of talent selection has been suggested by Gagné (2004) and Rees et al. (2016) who indicated a range of influential factors on talent selection such as personal catalysts, environmental catalysts and practice history. Secondly, the results of Chapter's 4 and 5 revealed that playing performance of young field hockey players is strongly influenced by the interaction between the three key constraints (Newell, 1986). Hence, appropriate training and competition environments should be created that are mindful of these interactive constraints to promote the development of necessary field hockey skills.

The dynamic nature of 'talent' selection is highlighted by the relative importance of different performance characteristics on the chance of being selected in a representative team. This influence of changing action capabilities on talent selection is also highlighted in soccer, where different performance characteristics influenced the selection into a representative team at different development stages (age) (Elferink-Gemser & Visscher, 2012). It can therefore be argued that a skilful player interacts with the current playing environment in the most efficient way, constrained by the rules of the game, while a talented player has the potential to interact with the future playing environment in the most efficient way. It is this difference between talent selection and talent identification that emphasises the difficulty of talent identification and this could potentially question the use of certain performance characteristics for talent identification. Although it is suggested in Chapter 3 that the multi-dimensional testing battery is able to distinguish between state and club level players, its ability to predict talent is not examined in the current study and any inferences about talent identification can therefore be questioned. Abbott et al. (2005) also argued that most testing batteries are perfectly able to identify the best performer at one point in time; however, selecting a potential expert performer is a complex process due to the nonlinear nature of development. If a young athlete doesn't display desired behaviour, this may because this behaviour is not yet triggered by the environment or because that type of behaviour is absent in the young athlete. Consequently, the earlier talent identification based on performance testing is utilised, the less reliable the selection of 'talented' players is (Abbott et al., 2005; Baker, Schorer, & Cobley, 2012).

From the first study it is clear that field hockey specific skills such as dribbling and passing/hitting abilities and physical skills such as speed and endurance are perceived as highly important performance characteristics required to play at a high level of competition in field hockey. To increase the talent pool in field hockey, policy makers should focus on improving field hockey technical skills as well as physical skills in a context that is representative of the performance setting (Pinder et al., 2011). Therefore, it is suggested that competition structures should be designed to provide youth players enough opportunities to become attuned to affordances to create relevant information-movement couplings. The findings of Chapter 4 suggest that an U12 competition structure with 8 players a side and smaller field dimensions provide players with more opportunities to develop their field hockey technical skills while the physical demands are similar to those of a full-field game. Furthermore, players are more involved and experience more success what is beneficial for their learning experience (Buszard, Farrow, Reid, & Masters, 2014). It is clear that these task constraints interact in a positive way with the organismic and environmental constraints of U12 youth field hockey players to promote the development of skills, however, it is emphasised that the optimal playing environments should be determined for different age groups as the organismic constraints alter which influences playing behaviour and skill development (Newell, 1986).

Examining the practice history of expert athletes, it is clear that invasion type activities such as SSG are important for the development of technical skills and decision-making skills (Berry et al., 2008).

It is hypothesised that SSG provide players with a learning environment that is representative of the performance context and where task constraints can be manipulated to promote specific behaviour (Davids, Araújo, Correia, & Vilar, 2013). The findings of Chapter 5 suggest that each specific manipulation of task constraints will influence the playing behaviour of players in a unique way and in turn the performance and potential development of skills. From a broader perspective of skill acquisition, the results of Chapter 5 can refute the argument often used by coaches that drills provide them with more volume of practice. If coaches get a clear understanding of the interaction between the three types of constraints in their sport, they're able to design game-based activities that lead to a great volume of practice while maintaining the coupling between specific perceptual information and movement (Renshaw et al., 2010). The benefits of playing game-based practice over drill-based practice is that players are able to develop sport-specific technical and decision-making skills under game-representative demands which is likely to increase the cognitive effort (Farrow et al., 2008) which is in turn associated with greater skill learning (Lee et al., 1994).

6.3 Theoretical Implications

In this thesis, two distinct processes on the road to sporting success were discussed: (1) the identification of key performance characteristics for selection into a representative with the use of a multi-dimensional performance testing battery and (2) the development of necessary field hockey skills with the use of invasion-type activities. The theoretical implications of these experiments are discussed below.

For many years, the selection of talented athletes has attracted the attention of sporting organisations and sports scientists. Over the years, the influence of several performance characteristics on performance level was determined to predict sporting success at a younger age. Although Bar-Or (1975) suggested a five-step process to talent identification, there was a lack of a theoretical framework for talent identification. A possible theoretical model, earlier proposed by Baker et al. (2012) that could adequately describe the dynamic nature of talent identification and talent selection is the constraints model of Newell (1986). Results from Chapter 3 highlight the dynamic nature of organismic, task and environmental constraints as they apply to talent selection. For example, the importance of endurance and high-speed running (a task constraint) is described by Jennings et al. (2012a) which is reflected in the superior speed and endurance capacities of state level players. Secondly, the influence of maturational status and practice history (individual constraints) on the selection for a state team was highlighted in the first study. Thirdly, the RAE only seems to influence talent selection at the U13 group (age-grouping is an environmental constraint) as growth (individual constraint) related advantages are the largest at this age. The strength of this model for talent identification and selection is that this model is able to conceptualise the notion that the 'talent' displayed by an athlete can change over time due to the interaction between the three types of constraints. Understanding the influence of several performance characteristics as well as sport organisation policies on talent selection will increase the predictive value of talent identification.

Furthermore, the interaction between the three types of constraints in the guidance of playing behaviour is emphasised by the results of Chapter 4 and 5. The findings in Chapter 4 showed that a similar constraint manipulation in Australian football (Davies et al., 2013), soccer (Owen, Twist, & Ford, 2004), water polo (Lupo et al, 2009) and field hockey didn't result in the same change of behaviour. An explanation for these differences is that a task constraint such as playing surface or ball characteristics will influence the interaction between the three types of constraints and in turn alter playing behaviour. The influence of this type of task constraint should be considered when manipulating the learning environment to promote skill development. The findings of Chapter 5 showed that manipulating field characteristics of SSG, without giving any instructions, altered the playing behaviour of U14 field hockey players. The technical skill, decision-making and physical demands of the SSG differ due to the change in perceptual information which influences the affordances of players (Renshaw et al., 2010). These changes in playing behaviour are likely to affect the development of field hockey technical skills, decision-making skills and physical abilities of players. Understanding the unique interaction of task constraints, organismic constraints and environmental constraints is of importance to create appropriate learning environments to develop all the necessary skills for field hockey players.

Over the last few decades, several talent development models are proposed based on retrospective training data of expert athletes (Côté, 1999; Ericsson, Krampe, & Tesch-Römer, 1993; Ford, Ward, Hodges, & Williams, 2009). The results of Chapter 3 revealed that state level players participated in field hockey at a younger age and they had invested significantly more hours in field hockey training from the age of 10 years compared to club level players. Because no detailed information on the type of activities of field hockey training is available, these findings could be interpreted to support the early engagement hypothesis (Ford et al., 2009) and deliberate practice theory (Ericsson et al., 1993). However, state and club level players also engaged in the same number of other sports (males around 2.5 other sports and females around 2.0 other sports) and invested a similar amount of hours into these sports. This implies that sampling multiple sports during the younger years doesn't hinder the development of field hockey skills, which is also consistent with the developmental model of sport participation (Côté, 1999). It is therefore suggested that Hockey Australia schedules the youth competition (field hockey is a winter sport in Australia) in such a way that players have the opportunity to compete in a different sport during the summer break. The engagement in this other organised sport will provide children with a different learning environment which is beneficial for their physical development as well as their cognitive and social development (Côté & Hancock, 2016; Côté, Lidor, & Hackfort, 2009).

6.4 Practical Implications

There are several practical implications from the findings of this thesis. Talent selection of talented field hockey players is influenced by several performance characteristics that are deemed to be important to compete at a high level of competition. To provide every player an equal chance to be considered as a 'talented' player, discriminating performance characteristics should be incorporated into a testing battery to support the selection of players for representative state teams. This need for a multi-dimensional approach to talent selection is supported in Australian football (Woods, Raynor, Bruce, McDonald, & Robertson, 2016), basketball (Torres-Unda et al., 2013) and soccer (Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2014; Unnithan, White, Georgiou, Iga, & Drust, 2012). When coaches and selectors use performance on a testing battery during the selection process, they should account for the maturational status and training history of the player before making a selection. Retrospective data of former expert athletes can provide normative values for certain performance characteristics at different ages and talented players can be compared against these normative values using their biological age. For example, the performance of former expert athletes on an endurance test during their developmental years creates a bandwidth of 'talented' performance (see Figure 6.1). When the performance on this endurance test of a young athlete with a specific biological age falls in or above the talent-bandwidth, he can be selected for a representative team based on this performance characteristic. Creating a talent-bandwidth for several important performance characteristics can improve the identification of future performers.

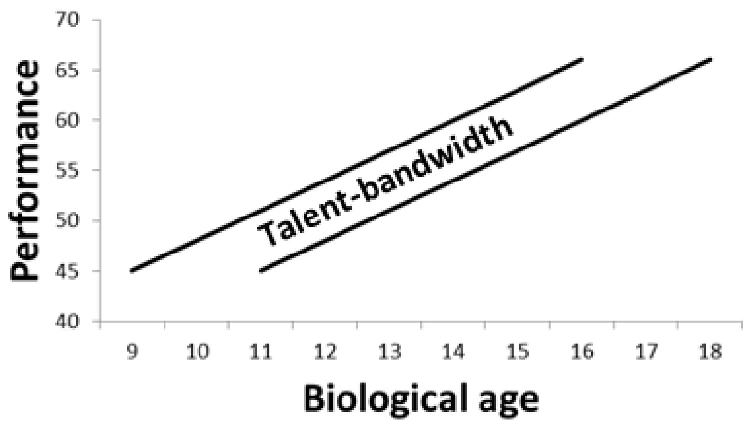

Figure 6.1. Example of a normative value graph for the identification of talented players.

The results from Chapter 4 indicated that the competition structure for U12 field hockey players should be changed from playing on a full-field with 11 players per side to playing on a half-field with 8 players per side. Firstly, due to the change of field dimensions and number of players, players will have more opportunities to develop field hockey technical and decision-making skills (as illustrated in Chapter 4). Secondly, the increase in the number of successful actions is associated with an increase in task engagement and young players seem to get more enjoyment out of playing environments where they experience greater success (Farrow & Reid, 2010; Buszard et al., 2014).

The results from Chapter 5 indicated that coaches and physical educators can manipulate task constraints of SSG to promote the development of specific field hockey skills in a representative learning environment (Pinder et al., 2011). It is suggested that players will improve their passing skill and associated decision-making skills when playing the possession game while playing the cage hockey game forces players to make quicker decision while being under higher physical demands compared to the normal game. The two goals game will provide players with more opportunities to improve their dribbling and scoring skills. Furthermore, it is argued that coaches and physical educators can manipulate the physical demands of SSG by manipulating the number of players; lowering the number of players will increase the physical demands by increasing the total distance covered and increasing running and high-speed running.

The movement solutions players will come up with in modified SSG are unique for each player as the interaction with the environment is dependent on their action capabilities. It is therefore proposed that SSG can be used during the selection procedure for a representative team. Results from Chapter 5 indicated that specific performance characteristics such as passing, dribbling or physical capacities can be highlighted when SSG were manipulated accordingly. It is suggested that experienced selectors and coaches manipulate SSG during selection trials in such way that key performance characteristics are displayed in an ecological setting. For example, the possession game can be used to identify the passing skills of young field hockey players while it is suggested that the two goals game is used to identify dribbling and scoring skills of young field hockey players. This game-centred approach to talent selection has been shown to be effective in ice-hockey and soccer (Nadeau, Godbout, & Richard, 2008; Waldron & Worsfold, 2010).

6.5 Limitations of thesis

The use of a cross-sectional study design to explore differences in anthropometric, physical capacity, sport-specific technical skills, decision-making skills, self-regulatory skills and practice history between talented and non-talented players has been shown to be effective (Elferink-Gemser et al., 2004; Huijgen et al., 2014; Vaeyens et al., 2006). However, it is clear that the development of sporting success is a dynamic process and that the performance on a testing battery at one point in time might not be able to fully explain and predict who will become an expert performer. Therefore, the lack of a follow up measurement to compare the performance level of players and their performance on the testing battery at another point in time is a limitation of the first study. The use of a follow-up measurement has been shown to be an appropriate method to examine discriminating performance characteristics and the predictive power of these characteristics (Falk, Lidor, Lander, & Lang, 2004; Lidor et al., 2005; Ostojic et al., 2014).

In Chapter 3, the passing and hitting tests for accuracy and the decision-making test were specially developed for this study. To measure the test-retest reliability of the tests, players performed the tests at two different occasions two weeks apart. Unfortunately, the test-retest reliability for the hitting for accuracy (ICC = -0.133) and decision-making test (ICC = 0.226) were not significant, which indicated that results of these tests should be interpreted with caution.

In Chapter 4, the group of participants is rather small and the influence of manipulating number of players and density on performance variables, activity profiles and positional data is only determined for one age group (under 14). As there weren't multiple age groups included in the study, the limiting factor in scaling field dimensions for competition structure for different developmental stages in field hockey couldn't be determined.

In Chapter 4, the participants were asked to play a match in four different conditions. The participants were familiar with two of the match conditions (standard numbers – standard density and the scaled numbers – scaled density conditions) while the other two conditions were totally new. This unfamiliarity could have influenced the playing behaviour of players and it's therefore suggested for future research to play a familiarisation game before the testing commences.

In Chapter 4 and 5, the influence of manipulating different task constraints on players' technical, decision-making and physical behaviour was examined. Although these experiments only examined a change in skill performance under changing task constraints, inferences are made about the development of technical and decision-making skills as well as about the development of physical capacity of players.

It is therefore suggested that these inferences are interpreted as such, however, it is argued that these inferences are justified based on the work of Turner and Martinek (1999) and Chatzopoulos, Drakou, Kotzamanidou, and Tsorbatzoudis (2006), who reported a significant improvement in skill performance after game-based training programs.

In Chapter 5, one of the field characteristics manipulations was the cage hockey game. This cage hockey game was chosen based on the similarities with the indoor field hockey game and therefore, it is suggested that players with indoor field hockey experience had an advantage over inexperienced indoor field hockey players. However, no information on indoor field hockey experience of the participants was reported.

6.6 Future directions

Chapter 3 provided an understanding about the relative importance of specific performance characteristics in field hockey by using a cross-sectional design. Future research should however adopt a more longitudinal approach to examine the predictive value of performance characteristics on sporting success in field hockey. It is suggested that each year, male and female field hockey players of the highest youth competitions in the state complete the field hockey testing battery, starting at the U12 competition. This cross-sectional and longitudinal approach will provide information about the predictive power of the performance on the testing battery at the junior level on sporting success at the senior level. Secondly, by following these young field hockey players for several years, the influence of amount, type and content of training on the development of field hockey technical skill, decision-making skill and physical capacity can be established.

The aim of Chapter 4 was to determine the influence of competition structure on playing behaviour of youth field hockey players. Results suggested that players interact with teammates and their opponents in such way that corresponds with their action capabilities. Therefore, future research should focus on the identification of age-matched competition structures based on their action capabilities, for example the passing ability (e.g., distance and accuracy). Findings of Gerdsen (2008) showed that height was a good predictor of kicking distance in soccer and it was argued to adapt field dimensions based on players physical (height) and kicking ability to create appropriate performance (and learning) environments. It is proposed that future research focuses on determining the relationship between action capabilities of young players and physical attributes to create appropriate competition environments for different age groups.

The findings of Chapter 4 and 5 implied that manipulating task constraints can promote the development of field hockey technical skills, decision-making skills and physical capacity. However, no measurement of development was taken and is suggested for future research. It is recommended that young field hockey players participate in a SSG training program where their field hockey technical skills, decision-making skills and physical capacities are measured at the commencement, halfway and at the conclusion of the training program. By manipulating several task constraints in different training groups, the effectiveness of SSG on the development of important field hockey skills can be examined.

6.7 Concluding Remarks

The main aims of this thesis were to understand what performance characteristics distinguished between skill levels at different stages of development and to gain more understanding of the influence of competition and training environment on the emergence of critical field hockey skills. The evidence put forward in this thesis highlights that the performance level in field hockey is influenced by a wide range of performance characteristics. Personal, environmental and practice and training characteristics dictates how ‘talented’ an athlete is and therefore influences the performance level and selection into a representative team. Furthermore, this thesis highlights playing behaviour is influenced by personal, environmental and task constraints and that a change in playing behaviour can be solely promoted by manipulating any of the three type of constraints (Newell, 1986). More so, it is argued that coaches and trainers can create and manipulate learning environments where players can develop specific field hockey skills.

In summary, this thesis has contributed to the understanding of performance testing and skill acquisition in field hockey. The adopted multi-dimensional approach to quantify skill and to quantify performance in youth field hockey provides a promising strategy for sporting organisations to monitor and develop the skills of young field hockey players.

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VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite your child to be a part of a study titled “Examining the key characteristics of field hockey players”. This study aims to examine the influence of six different field hockey tests for players aged 12 through to seniors. This holistic test battery will become a very useful tool for coaches to assess their athletes' skill and monitor the development of players. The project requires your child to perform different physical and field hockey skill tests, as well as filling in multiple questionnaires. While participating in this study, your child risks getting injured eg; soft tissue injury, and there are minor psychological and social risks in testing of this nature. If your child will be overwhelmed by any of the result that will come forward during participation in this study, you will be informed and advised and Dr Janet Young (ph +61 3 9919 4762) will be available as a professional counsellor through Victoria University who can be contacted for advice regarding counselling services'

CERTIFICATION BY SUBJECT

I, ____ (parent/guardians name)

of ____ (parent/guardians suburb)

certify that I am at least 18 years old and that I am voluntarily giving my consent for

my child ____ (participant/child's name)

to participate in a study titled: “Examining the key characteristics of field hockey players” being conducted by Victoria University researchers and Hockey Australia.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by:

Ewout Timmerman, and that I freely consent to my child's participation involving the below mentioned procedures:

- Body composition measurements
- Performing technical skill tests
- Performing physical tests
- Performing a decision making test
- Filling in questionnaires

I certify that I have had the opportunity to have any questions answered and that I understand that my child can withdraw from this study at any time and that this withdrawal will not jeopardise me or my child in any way.

For further research into the key characteristics of field hockey players, the researchers can contact me for a follow-up study:

□ Yes

□ No

I have been informed that the information my child provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researchers

Professor Damian Farrow

Professor of Sport Science, Institute of Sport Exercise and Active Living

+61408445701

Ewout Timmerman, M.Sc

PhD student at the Institute of Sport Exercise and Active Living

+61415752780

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

Your child is invited to participate

Your child is invited to participate in a research project entitled “Examining the key characteristics of field hockey players”.

This project is being conducted by student researcher Ewout Timmerman as part of his PhD study at Victoria University under the supervision of Prof. Damian Farrow from the College of Sport and Exercise Science.

Project explanation

Your child is invited to participate in a research study that is examining the key characteristics of field hockey players. In total six different characteristics will be measured: body composition, physical, technical, decision making, learning motivation and sport history characteristics. Field hockey players from different ages, different skill levels and both sexes will perform the tests to create a clear overview on how the various components tested influence player development. This holistic test battery will then be used to develop a useful tool for coaches to assess their athletes’ skills and to monitor the development of their players.

What will your child be asked to do?

Your child will be asked to undergo multiple tests at Victoria University, Melbourne, all performed on one day. The body composition variables will be measured by using a bioelectrical impedance scale, where your child have to stand on a scale while electrodes in the foot sensor pads send a low, safe electrical signal through the body. To measure the physical abilities of your child, he/she will be asked to perform maximal jumps for height, a 40-metre sprint and a multi-stage run test (commonly called a beep test used to measure endurance). To measure field hockey skills, your child will be asked to perform hockey dribble, passing and hitting tasks. To measure the ability to make decisions during the game of hockey, your child will perform a decision-making test that simulates game situations using a life-size video projection screen. At the completion of the physical and technical testing your child will be asked to fill in two questionnaires, one about self-regulation, or how your child views their personal approach to skill learning, and one questionnaire about their sport-history, that is what sports has your child played up till now and for how long .

What will your child gain from participating?

Your child will be provided with a summary of their own results on the six key characteristics measured relative to how an elite field hockey player performs and relative to their own age group and gender. Your child will only receive his/her own results and researchers will make sure that other individuals won’t have access to your child’s results. This information could then be reviewed by yourself and your child to highlight the key skills that need to be practised at the junior development level.

How will the information your child gives be used?

The findings of this research will help coaches better understand the influence of the six key characteristics on the development of field hockey players and consequently adjust their programs to better coach these qualities..

Also the findings of this study will be presented in the form of a scientific publication and a PhD thesis. This means other coaches and scientists will be able to benefit from the knowledge gained from this study. Some of the recordings from the testing might be used at presentations for Hockey Australia and/or conferences to show differences in decision making between players. Please note that your child will not be named within any reporting and there is a negligible chance that someone outside of the team of researchers will be able to identify your child's results at any time during or following the study.

What are the potential risks of participating in this project?

The participation of your child is voluntary and is in no way required because your child is a member of Hockey Victoria. In addition, if you give consent to participate, your child is free to withdraw that consent at any time, without reason and without penalty. While participating in this study your child is exposed to minimal physical and psychological risks. Physically there is a minor risk of injury eg; soft tissue strain. A thorough warm-up will be completed to minimise the likelihood of this occurring. Similarly there are minor psychological and social risks in testing of this nature. To minimise these risk, the tests that might upset participants will be done on an individual base and results will not be reported to the participants self. If your child will be overwhelmed by any of the result that will come forward during participation in this study, you will be informed and advised and Dr Janet Young (ph +61 3 9919 4762) will be available as a professional counsellor through Victoria University who can be contacted for advice regarding counselling services.

How will this project be conducted?

If your child is willing to participate in this study, he/she and other teammates will be invited to come to Victoria University, Melbourne. At Victoria University, different testing stations will be set up, where the different tests will be explained by one of the researchers. If everything is clear, the participants will first fill in the questionnaires, then perform all the tests in pairs at the different stations and at the end all the participants will perform the multi-stage run test. Each participant will receive their individual results after testing via email.

Who is conducting the study?

Victoria University & Hockey Australia.

Professor Damian Farrow

Professor of Sport Science, Institute of Sport Exercise and Active Living

Telephone: 0408445701

Ewout Timmerman, M.Sc.

Phd Student at the Institute of Sport Exercise and Active Living

Telephone: 0415752780

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

THE DEVELOPMENTAL HISTORY OF ATHLETES QUESTIONNAIRE

Please note: This page will be removed and separated from the remainder of the questionnaire. Your responses will remain completely anonymous.

Name:	
Date of birth	
Today's date:	

DD / MM / YYYY

Section 1 of 3: Your Representative History

Within a single year of involvement, athletes often participate in their main sport at multiple levels of competition.

For example, a 16 year-old field hockey player may play for their local club team in the 16 years and the Open age group categories, while also playing for their state / provincial team in the Under 18 years age group category. In this case, at age 16, the athlete competed against others within the local area at both the junior and senior / open levels, as well against others within the state / province at the junior level.

The following section relates to your ***participation in the various levels of competition*** *across your career in your main sport.*

For each year of your involvement in your main sport, please indicate the levels of competition in which you participated by checking the appropriate boxes in the chart below.

As outlined in section three, junior age group categories can vary from sport to sport. When answering this question please think about your participation in competitions that would be classified as junior level competition according to the rules of your main sport. Junior age group categories typically require athletes to be below a particular age at the time of competition. Senior / open competition refers to adult competition. In some sports for reasons relating to safety, a lower age limit may apply, however in the majority of cases senior / open competitions are free of age restrictions, allowing junior athletes to participate in senior / open competitive events. Any competition involving participation against adults is classified as senior / open competition.

More than one response is permitted in each box below, so please check all relevant age group categories that you participated in during each year of your involvement in your main sport.

	Competition against others within the ***local area***	*Competition against others within the* ***state / province***	*Competition against others from* ***across the country***	*Competition against others from* ***different countries***
Example	☒ Junior level competition ☒ Senior / open level competition ☐ I did not compete at this level	☒ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☒ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☒ I did not compete at this level

	*Competition against others within the **local area***	*Competition against others within the **state / province***	*Competition against others from **across the country***	*Competition against others from **different countries***
Age 5	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 6	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 7	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 8	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 9	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 10	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level

	*Competition against others within the **local area***	*Competition against others within the **state / province***	*Competition against others from **across the country***	*Competition against others from **different countries***
Age 11	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 12	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 13	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 14	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 15	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 16	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level

	*Competition against others within the **local area***	*Competition against others within the **state / province***	*Competition against others from **across the country***	*Competition against others from **different countries***
Age 17	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 18	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 19	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 20	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level
Age 21	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level	☐ Junior level competition ☐ Senior / open level competition ☐ I did not compete at this level

Section 2 of 3: Your Practice History

*We would now like to ask about your practice history for your main sport. The following section takes a detailed look into the **amount of practice** and the **types of practice** activities that you have engaged in throughout your career in your main sport to date.*

The next set of questions will address your participation in:

1. ***Sport specific physical practice***
2. ***Physical preparation** (e.g. strength and conditioning, weights, fitness, pilates, yoga, flexibility)*
3. ***Informal play** involving activities relating to your main sport (e.g. pick-up basketball, street hockey, swimming in the backyard pool)*
4. ***Training camps***

First, we would like to ask about your participation in **sport specific physical practice** for your main sport.

Sport specific physical practice includes those **activities that directly resemble the technical and/or tactical demands associated with your main sport**. These activities require physical effort as well as concentration, and are aimed directly at improving performance.

Please note that sport specific physical practice **does not include**:

- Non-sport specific physical preparation activities such as strength and conditioning, weights, fitness, yoga, pilates, or flexibility.
- Informal playful games relating to your main sport that you engage in for fun with friends and family such as pick-up basketball, street hockey, or swimming in the backyard pool.

Your involvement in these activities will be discussed in a moment.

There are four conditions in which sport specific physical practice can take place:

1. A **coach is present** at the training venue providing supervision to **you and 1 or more other athletes**.
2. A **coach is present** at the training venue providing **one-on-one** supervision to you and only you in an individual practice session.
3. **No coach** is present to provide supervision but **you and 1 or more other athletes** are practicing together.
4. **No coach** is present to provide supervision, no-one else is practicing with you, but you are practicing **on your own**.

The next questions relate to your participation in sport specific physical practice under each of the four conditions described above. **Please consider your involvement in each of the four practice conditions separately.**

During each year of your participation in sport specific physical practice for your main sport, please indicate how many hours per week (on average) you engaged in this type of activity within the four conditions outlined below, and for how many months of the year.

	*A **coach is present** at the training venue providing supervision to **you and 1 or more other athletes***		*A **coach is present** at the training venue providing **one-on-one** supervision to you and only you in an individual practice session*		***No coach** is present to provide supervision but **you and 1 or more other athletes** are practicing together*		***No coach** is present to provide supervision, no-one else is practicing with you, but you are practicing **on your own***	
	Hours per week	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*
Example	6	10	1	10	0	0	1	12
Age 5								
Age 6								
Age 7								
Age 8								
Age 9								
Age 10								
Age 11								
Age 12								
Age 13								
Age 14								
Age 15								
Age 16								

	*A **coach is present** at the training venue providing supervision to **you and 1 or more other athletes***		*A **coach is present** at the training venue providing **one-on-one** supervision to you and only you in an individual practice session*		***No coach** is present to provide supervision but **you and 1 or more other athletes** are practicing together*		***No coach** is present to provide supervision, no-one else is practicing with you, but you are practicing **on your own***	
	Hours per week	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*
Age 17								
Age 18								
Age 19								
Age 20								
Age 21								

Next, we would like to ask about your participation in **physical preparation activities** for your main sport.

Physical preparation includes all activities aimed at **improving physiological and muscular capacities** such as strength, power, endurance, and flexibility. Examples of physical preparation activities include, but are not limited to, strength and conditioning, weights, fitness, pilates, yoga, and flexibility training.

These activities are sometimes completed during sport specific physical practice sessions, however, for the following questions please refer only to your participation in physical preparation activities **completed outside of sport specific physical practice** as separate stand-alone practice sessions.

There are four conditions in which physical preparation activities can take place:

1. A **coach / specialised instructor is present** at the training venue providing supervision to **you and 1 or more other athletes**.
2. A **coach / specialised instructor is present** at the training venue providing **one-on-one** supervision to you and only you in an individual training session.
3. **No coach / specialised instructor** is present to provide supervision but **you and 1 or more other athletes** are training together.
4. **No coach / specialised instructor** is present to provide supervision, no-one else is training with you, but you are training **on your own**.

The next questions relate to your participation in physical preparation activities under each of the four conditions described above. **Please consider your involvement in each of the four training conditions separately.**

During each year of your participation in physical preparation activities for your main sport, please indicate how many hours per week (on average) you engaged in this type of activity within the four conditions outlined below, and for how many months of the year.

If you have never participated in physical preparation activities for your main sport please place a tick in the box below and continue to page 12:

☐ I have never participated in physical preparation activities for my main sport

	*A **coach / specialised instructor is present** at the training venue providing supervision to **you and 1 or more other athletes***		*A **coach / specialised instructor is present** at the training venue providing **one-on-one** supervision to you and only you in an individual training session*		***No coach / specialised instructor** is present to provide supervision but **you and 1 or more other athletes** are training together*		***No coach / specialised instructor** is present to provide supervision, no-one else is training with you, but you are training **on your own***	
	Hours per week	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*
Example	4	10	0	0	2	12	2	12
Age 5								
Age 6								
Age 7								
Age 8								
Age 9								
Age 10								
Age 11								
Age 12								
Age 13								
Age 14								

	A **coach / specialised instructor is present** at the training venue providing supervision to **you and 1 or more other athletes**		A **coach / specialised instructor is present** at the training venue providing **one-on-one** supervision to you and only you in an individual training session		**No coach / specialised instructor** is present to provide supervision but **you and 1 or more other athletes** are training together		**No coach / specialised instructor** is present to provide supervision, no-one else is training with you, but you are training **on your own**	
	Hours per week	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*	*Hours per week*	*Months per year*
Age 15								
Age 16								
Age 17								
Age 18								
Age 19								
Age 20								
Age 21								

The following question relates to your participation in **informal play** involving activities relating to your main sport.

Informal play includes activities that **resemble the skills and goals of your main sport** but involve **modified rules and/or equipment**, with very little to **no formal instruction, coaching, or supervision**. The main emphasis of these activities is on fun and enjoyment rather than performance improvement.

Informal play relating to your main sport often occurs in the home, the backyard, the school yard, the local park, and/or the local streets. Examples for basketball may include pick-up basketball or shooting hoops for fun with friends. Examples for swimming may include swimming at the beach or playing in the backyard pool with your family.

Please note: These questions relate to informal play involving activities **relating to your main sport only**. Your participation in informal play involving other sporting games will be addressed elsewhere.

There are two conditions in which informal play relating to your main sport can take place:

1. **With 1 or more other people** such as your team mates, friends, or family.
2. **On your own**.

The next questions relate to your participation in informal play relating to your main sport under each of the conditions described above. **Please consider your involvement in each of the conditions of play separately.**

During each year of your participation in informal play involving activities relating to your main sport, please indicate how many hours per week (on average) you engaged in this type of activity within the two conditions outlined below, and for how many months of the year.

If you have never participated in informal play involving activities relating to your main sport please place a tick in the box below and continue to the bottom of page 14:

☐ I have never participated in play involving activities relating to my main sport

	With 1 or more other people *such as your team mates, friends, or family*		***On your own***	
	Hours per week	*Months per year*	*Hours per week*	*Months per year*
Example	2	8	4	12
Age 5				
Age 6				
Age 7				
Age 8				

	With 1 or more other people *such as your team mates, friends, or family*		***On your own***	
	Hours per week	*Months per year*	*Hours per week*	*Months per year*
Age 9				
Age 10				
Age 11				
Age 12				
Age 13				
Age 14				
Age 15				
Age 16				
Age 17				
Age 18				
Age 19				
Age 20				
Age 21				

The following question relates to your participation in **training camps** for your main sport.

Training camps refer to **intensive periods of training** during which your team comes together for an extended time to participate in practice activities that **exceed your regular** week to week training commitments.

Training camps can last from one weekend to several months in duration, and they are often held at a location away from your regular training venue.

Typical activities involved in a training camp include sport specific physical practice, supplementary practice activities such as physical conditioning and video review, education sessions, team building exercises, and mock competitions.

Training camps are commonly held in the pre-season training period or in the lead up to an important competition. They can also serve as a regular practice opportunity for teams who do not train together on a weekly basis.

For each year of your involvement in training camps for your main sport, please indicate the total number of days, weeks, and/or months you spent in training camps.

If you participated in multiple training camps within a single year, please add the total number of days, weeks, and/or months you spent in training camps together to provide an overall total duration for the year.

If you have never participated in any training camps for your main sport please place a tick in the box below and continue to page 16:

☐ I have never participated in training camps for my main sport

	Total number of days, weeks, and/or months spent in training camps
Example 1	4 Days _____ Weeks _____ Months
Example 2	_____ Days 2 Weeks 2 Months
Age 5	Days Weeks Months
Age 6	Days Weeks Months
Age 7	Days Weeks Months
Age 8	Days Weeks Months
Age 9	Days Weeks Months
Age 10	Days Weeks Months
Age 11	Days Weeks Months
Age 12	Days Weeks Months
Age 13	Days Weeks Months
Age 14	Days Weeks Months
Age 15	Days Weeks Months
Age 16	Days Weeks Months
Age 17	Days Weeks Months
Age 18	Days Weeks Months
Age 19	Days Weeks Months
Age 20	Days Weeks Months
Age 21	Days Weeks Months

Section 3 of 3: Your Participation in Other Organised Sports

Athletes often participate in a variety of sports before choosing to specialise in their main sport.

*The following questions relate to your involvement in **organised sports other than your main sport**.*

*Organised sports include sporting activities in which you have **regular practice sessions** under the **formal supervision** of a coach or adult. They may or may not involve competitions. Participation in organised sports often requires registration with a team or a club.*

When answering the following questions about your involvement in other organised sports, please do not include sporting activities completed as part of compulsory physical education classes at school, but do include any school sporting activities in which you participated in regular, supervised practice sessions.

*Also, **please do not include the informal playful sporting games** that you engage in every now and again, for fun with your friends and family, in the back yard or local streets (such as pick-up basketball or street hockey).*

*Please include all organised sports that you participated in for **at least one season or more**, but do not include your main sport.*

For each year of your involvement in all of the organised sports that you participated in, please indicate:

a) The type of sport. Please be specific as possible e.g. indoor volleyball, football–soccer, football–american, field hockey, ice hockey etc.

b) How many hours per week (on average) you were involved in all practice and competition activities relating to that sport.

c) How many months of the year you were involved in that sport.

d) The highest level of competition that you participated at for that sport. To identify the highest level of competition that you participated at please refer to the codes provided on the back page of this questionnaire. You may rip off the back page for your convenience. For example, please enter a '5' in the box below if the highest level of competition you participated at for a particular age was "competition against others within the local area, at the senior / open level".

If you have never participated in any other organised sports other than your main sport please place a tick in the box below and continue to page 22:

☐ I have never participated in any other organised sports other than my main sport

Appendix C. Modified version of the Developmental History of Athletes Questionnare (DHAQ).

	Sport 1			***Sport 2***			***Sport 3***		
	Hours per week	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*
Example	Swimming			Basketball			Artistic Gymnastics		
	4	6	8	2	5	4	3	11	1
SPORT									
Age 5									
Age 6									
Age 7									
Age 8									
Age 9									
Age 10									
Age 11									
Age 12									
Age 13									

	Sport 1			*Sport 2*			*Sport 3*		
	Hours per week	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*
Age 14									
Age 15									
Age 16									
Age 17									
Age 18									
Age 19									
Age 20									
Age 21									

	Sport 4			***Sport 5***			***Sport 6***		
	Hours per week	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*
Example	Swimming			Basketball			Artistic Gymnastics		
	4	6	8	2	5	4	3	11	1
SPORT									
Age 5									
Age 6									
Age 7									
Age 8									
Age 9									
Age 10									
Age 11									
Age 12									
Age 13									

	Sport 4			*Sport 5*			*Sport 6*		
	Hours per week	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*	*Hours per week*	*Months per year*	*Highest level of competition*
Age 14									
Age 15									
Age 16									
Age 17									
Age 18									
Age 19									
Age 20									
Age 21									

Congratulations!

You have now completed the Developmental History of Athletes Questionnaire.

Thank you very much for your time, patience, co-operation, and assistance. Your participation in this research project is extremely valuable.

Level of Competition Code Sheet

Please use this code sheet to answer Section 6 of 8: Your Participation in Other Organised Sports

You may remove this page for your convenience.

To identify the highest level of competition when responding to items within section 6, please refer to the codes provided below.

For example, please enter a '5' in the relevant space if the highest level of competition is "competition against others within the local area at the senior / open level".

1. No competition - Recreational involvement only at the junior level
2. No competition - Recreational involvement only at the senior / open level
3. No competition - Recreational involvement only at the masters level
4. Competition against others within the local area at the junior level
5. Competition against others within the local area at the senior / open level
6. Competition against others within the local area at the masters level
7. Competition against others within the state / province at the junior level
8. Competition against others within the state / province at the senior / open level
9. Competition against others within the state / province at the masters level
10. Competition against others from across the country at the junior level
11. Competition against others from across the country at the senior / open level
12. Competition against others from across the country at the masters level
13. Competition against others from different countries at the junior level
14. Competition against others from different countries at the senior / open level
15. Competition against others from different countries at the masters level
16. Other – Please be sure specify the appropriate level of competition in the corresponding space

Name:____ **Sex:** ☐ **Male /** ☐ **Female** **Date of birth (DD/MM/YY):** ____________________

We would like you to indicate the extent to which you believe each statement to be true for you.

Remember, there are no right or wrong answers. Each child is different and we would like to know more about you.

		Almost Never	Sometimes	Often	Almost Always
1	I decide how to solve a problem before I begin				
2	I picture the steps of a plan that I have to follow				
3	I ask questions to myself about a problem before acting out the solution				
4	I imagine the parts of a problem I still have to complete				
5	I carefully plan my course of action to solve a problem				
6	I outline my goals and the steps needed to accomplish them				
7	I clearly plan my course of action before solving a problem				
8	I develop a plan for the solution of a problem				

		Almost Never	Sometimes	Often	Almost Always
9	I check how well I am doing while solving a task				
10	I check my work while I'm working on a task				
11	I ask myself how well I am doing while working a task				
12	I correct my errors				
13	I check my performance as I progress through a task				
14	I judge the correctness of my work				

		Almost Never	Sometimes	Often	Almost Always
15	I keep working, even on difficult tasks				
16	I try my best when performing a task				
17	I fully concentrate when I do a task				
18	I don't give up, even if the task is hard				
19	I work hard on a task, even if it is not important				
20	I work hard to do well, even if I don't like a task				
21	If I'm not really good at a task, I can compensate for this by working hard				
22	I am willing to do extra work on tasks, to make sure I learn more				

		Almost Never	Sometimes	Often	Almost Always
23	If I persist on a task, I will eventually succeed				
24	I know how to handle unforeseen situations because I know strategies to cope with things that are new to me				
25	If someone opposes me, I can find means and ways to get what I want				
26	I am confident that I could deal efficiently with unexpected events				
27	If I am in a tricky situation, I can usually think of something to do to solve the problem				
28	I remain calm when facing difficulties, because I know ways to cope with difficulties				
29	I always manage to solve difficult problems if I try hard enough				
30	It is easy for me to concentrate on my goals and to accomplish them				
31	I can solve most problems if I put necessary effort in				
32	When I am confronted with a problem, I usually find several solutions				
33	No matter what comes my way, I am usually able to handle it				

		Never	Seldom	Sometimes	Often	Always
34	I look back and check if what I did was right					
35	I double-check to make sure if I did it right					
36	I check to see if my calculations are correct					
37	I look back to see if I performed the correct procedures					
38	I check my work all the way through the problem					
39	I look back at the problem to see if my answer makes sense					
40	I stop and rethink a step I have already done					
41	I make sure I complete each step					

		Strongly Disagree	Disagree	Don't know	Agree	Strongly Agree
42	I evaluate my experiences so I can learn from them					
43	I try to think about my strength and weaknesses					
44	I think about my actions to see whether I can improve them					
45	I think about my past experience to understand my new ideas					
46	I try to think about how I can do things better next time					

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite your child to be a part of a study titled "The influence of the number of players and density on game dynamics in field hockey". This study aims to examine the practical implications for field hockey skill development of manipulating the number of players and density during competition matches. The project requires your child to play four different matches of 30 minutes, every match will be on a pitch with different dimensions but otherwise they will play field hockey as they would during a typical competition match. There are risks associated with participation in this study and therefore all precautions will be taken to ensure the safety of your child.

CERTIFICATION BY SUBJECT

I, ____ (parent/guardians name)

of ____ (parent/guardians suburb)

certify that I am at least 18 years old and that I am voluntarily giving my consent for

my child ____ (participant/child's name)

to participate in a study titled: "The influence of the number of players and density on game dynamics in field hockey" being conducted by Victoria University researchers and Hockey Australia.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by:

Ewout Timmerman, and that I freely consent to my child's participation involving the below mentioned procedures:

- Playing four field hockey matches of 30 minutes
- Video recording of the match-play.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw my child from this study at any time and that this withdrawal will not jeopardise me or my child in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher's

Professor Damian Farrow

Professor of Sport Science, Institute of Sport Exercise and Active Living

+61408445701

Ewout Timmerman, M.Sc

PhD student at the Institute of Sport Exercise and Active Living

+61415752780

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

Your child is invited to participate in a research project entitled “The influence of the number of players and density on game dynamics of field hockey”.

This project is being conducted by student researcher Ewout Timmerman as part of his PhD study at Victoria University under the supervision of Prof. Damian Farrow from the College of Sport and Exercise Science.

Project explanation

Your child is invited to participate in a research study that is analysing the influence of number of players and density on game dynamics of 12 and under field hockey game play. In total four different matches will be played. Two of the four games are similar to standard U10 and U12 competition matches that your child currently plays. In the other two matches one of the factors; the number of players or density (players / area) will be manipulated. Your child will be filmed when playing the four different matches. These video recordings will be used to analyse game dynamics for individual and team characteristics. This study aims to establish guidelines for match play (and training) for the development of young field hockey players.

What will my child be asked to do?

Your child will perform four matches of 70 minutes with at least 2 days between every match-day. As mentioned before, two of the four games are similar to standard competition matches. In the other two games, only the dimensions and the number of players are manipulated. Your child will be filmed when performing each field hockey match and their heart rate will be monitored by wearing a standard heart rate monitor.

What will my child gain from participating?

Your child will be provided with a summary of their game performances relative to how an elite hockey player plays the game. This information could then be reviewed yourself and your child to highlight the key skills that need to be practised at the junior development level.

How will the information my child gives be used?

The findings of this research will help coaches better understand the influence of number of players and density on game dynamics in field hockey. Thereby coaches are able to better match the training set-up with their aims and what will be beneficial for skill development.

Also the findings of this study will be presented in the form of a journal publication and a thesis. This means other coaches and scientists will be able to benefit from the knowledge gained from this study. Some of the recordings might be used at presentation for Hockey Australia and/or conferences to show differences between the four game structures. Please note that your child will not be named within this report and there is a low chance that someone outside of the team of researchers will be able to identify your child’s results at any time during or following the study.

What are the potential risks of participating in this project?

While participating in this study, your child risks getting injured eg; soft tissue injury or getting hit by a ball as they would be during normal field hockey training or competition. All the necessary precautions to minimise the likelihood of this occurring will be taken.

How will this project be conducted?

After filming the match-play of your child, these recordings will be analysed by using a field hockey analysis program where variables will be entered into this program for team and individual analysis. The coding will be done by one of the researchers and will be compared with game dynamics of the Australian Olympic hockey team.

Who is conducting the study?

Victoria University & Hockey Australia.

Professor Damian Farrow

Professor of Sport Science, Institute of Sport Exercise and Active Living

Telephone: 0408445701

Ewout Timmerman, M.Sc.

Phd Student at the Institute of Sport Exercise and Active Living

Telephone: 0415752780

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Performance variables

Successful pass

Analyses of the number of successful passes per player per condition revealed a significant main effect for number of players ($F_{1.10}$=4.748, P=0,054, η_p^2=0.332) but no significant main effect for density ($F_{1.10}$=0.207, P=0.659, η_p^2=0.020). No significant number of players x density interaction was found ($F_{1.10}$=0.786, P=0.396, η_p^2=0.073). Further exploration showed that the scaled density – scaled numbers condition differed significantly from the scaled density – standard numbers condition (P=0.030). A decrease in the number of players increased the amount of successful passes with 2.682 (95% CI [-0.061, 5.424]).

Unsuccessful pass

Analyses of the number of unsuccessful passes per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=0.239, P=0,635, η_p^2=0.023) and density ($F_{1.10}$=0.791, P=0.395, η_p^2=0.073), and no number of players x density interaction ($F_{1.10}$=1.412, P=0.262, η_p^2=0.124).

Total passes

Analyses of the number of total passes per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=3.371, P=0,096 η_p^2=0.252) and density ($F_{1.10}$=0.001, P=0.972, η_p^2=0.000), and no number of players x density interaction ($F_{1.10}$=1.420, P=0.261, η_p^2=0.124).

Successful dribble

Analyses of the number of successful dribbles per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=3.804, P=0.08, η_p^2=0.276) and density ($F_{1.10}$=0.026, P=0.847, η_p^2=0.003) and no number of players x density interaction ($F_{1.10}$=0.059, P=0.813, η_p^2=0.006).

Unsuccessful dribbles

Analyses of the number of unsuccessful dribbles per player in each condition shows a main effect for density ($F_{1.10}$=5.184, P=0.046, η_p^2=0.341) but no main effect for number of players ($F_{1.10}$=0.387, P=0.548, η_p^2=0.037). Also no number of players x density interaction effect was found ($F_{1.10}$=1.279, P=0.284, η_p^2=0.113). Minimising the personal playing area per player decreased the number of unsuccessful dribbles per player by 0.591 (95% CI [-1.169 , -0.013]).

Total dribbles

Analyses of the total number of dribbles per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=4,282, P=0.065, η_p^2=0.300) and density ($F_{1.10}$=0.625, P=0.448, η_p^2=0.059) and no number of players x density interaction ($F_{1.10}$= 0.419, P=0.532, η_p^2=0.040).

Skilled actions

Analyses of the total number of skill actions per player per condition revealed a significant main effect for the number of players ($F_{1.10}$=7.466, P=0.021, η_p^2=0.427) but no significant main effect for density ($F_{1.10}$=0.094, P=0.765, η_p^2=0.009). No significant number of players x density interaction was found ($F_{1.10}$=1.172, P=0.304, η_p^2=0.105). Further exploration showed that the scaled density – scaled numbers condition differed significantly from the scaled density – standard numbers condition (P=0.022). A decrease in the number of players increased the number of skill actions by 3.727 (95% CI [0.688 , 6.767]).

Successful actions

Analyses of the total number of successful actions per player per condition revealed a significant main effect for the number of players ($F_{1.10}$=6.832, P=0.026, η_p^2=0.406) but no significant main effect for density ($F_{1.10}$=0.139, P=0.717, η_p^2=0.014). No significant number of players x density interaction was found ($F_{1.10}$=0.246, P=0.631, η_p^2=0.024). Further exploration showed that the scaled density – scaled numbers condition differed significantly from the scaled density – standard numbers condition (P=0.011). A decrease in the number of players increased the number of successful actions by 3.773 (95% CI [0.557 , 6.989]).

Unsuccessful actions

Analyses of the total number of unsuccessful actions per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=0.003, P=0.954, η_p^2=0.000) and density ($F_{1.10}$=2.302, P=0.160, η_p^2=0.187) and no number of players x density interaction ($F_{1.10}$=1.710, P=0.220, η_p^2=0.146).

High pressure (<1m)

Analyses of the number of high pressure moments per player per condition revealed a significant main effect for number of players ($F_{1.10}$=8.637, P=0,015 η_p^2=0.463), but no main effect for density ($F_{1.10}$=3.056, P=0.111, η_p^2=0.234). Also there was no number of players x density interaction found ($F_{1.10}$=1.426, P=0.260, η_p^2=0.125). Further exploration showed that the scaled density – scaled numbers condition differed significantly from the scaled density – standard numbers condition (P=0.011). A decrease in the number of players increased the number of high pressure moments per player by 1.227 (95% CI [0.297 , 2.158]).

Medium pressure (1-5m)

Analyses of the number of medium pressure moments per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=1.341, P=0,274, η_p^2=0.118) and density ($F_{1.10}$=0.022, P=0.884, η_p^2=0.002), and no number of players x density interaction ($F_{1.10}$=0.236, P=0.637, η_p^2=0.023).

Low pressure (>5m)

Analyses of the number of low pressure moments per player per condition revealed a significant main effect for number of players ($F_{1.10}$=5.172, P=0,046, η_p^2=0.341), but no main effect for density ($F_{1.10}$=2.863, P=0.120, η_p^2=0.224). There was also no significant number of players x density interaction found ($F_{1.10}$=2.872, P=0.121, η_p^2=0.223). Further exploration showed that the scaled density – scaled numbers condition differed significantly from both the standard density – standard numbers condition (P=0.026) and the scaled density – standard numbers condition (P=0.033). A decrease in the number of players increases the number of low pressure moments per player by 1.364 (95% CI [0.028 , 2.700]).

Activity profiles

Odometer

Analyses revealed a significant interaction between number of players x density ($F_{1.10}$=14.172, P=0.004, η_p^2=0.586) for the total distance covered in metres. No significant main effect was found for number of players ($F_{1.10}$=0.069, P=0.799, η_p^2=0.007) and density ($F_{1.10}$=2.454, P=0.148, η_p^2=0.197). Further exploration showed that the standard density – standard numbers condition differed significantly from both the standard density – scaled numbers (P=0.013) and scaled density – standard players (P=0.003) conditions. Similar significant differences were found between the scaled density – scaled numbers condition and both the standard density – scaled numbers (P=0.019) and the scaled density – standard numbers (P=0.042) conditions (Table 3).

Metres per minute

Analyses revealed a significant number of players x density interaction ($F_{1.10}$=13.289, P=0.004, η_p^2=0.571) for the metres per minute. No significant main was found for number of players ($F_{1.10}$=0.144, P=0.713, η_p^2=0.014) and density ($F_{1.10}$=2.758, P=0.128 η_p^2=0.216). Further exploration showed that the standard density – standard numbers condition differed significantly from both the standard density – scaled numbers (P=0.019) and scaled density – standard players (P=0.003) conditions. Similar differences were found between the scaled density – scaled numbers condition and both the standard density – scaled numbers (P=0.024) and the scaled density – standard numbers (P=0.041) conditions.

Maximum speed

Analyses of the maximum speed reached per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=0.438, P=0.523, η_p^2=0.042) and density ($F_{1.10}$=1.011, P=0.0.338, η_p^2=0.092), and no number of players x density interaction was found ($F_{1.10}$=1.154, P=308, η_p^2=0.103).

Distance covered walking (0-3 km/h)

Analyses of the distance covered in the 0-5 km/h zone per player per condition revealed no significant effects. No main effect for number of players ($F_{1.10}$=2.649, P=0.135, η_p^2=0.209) and density ($F_{1.10}$=2.183, P=0.170, η_p^2=0.1799), and no number of players x density interaction was found ($F_{1.10}$=0.909, P=0.363, η_p^2=0.083).

Distance covered jogging (3-8 km/h)

Analyses revealed a significant number of players x density interaction ($F_{1.10}$=5.124, P=0.047, η_p^2=0.339) for the distance covered in the 3-8 km/h zone. No significant main effect was found for number of players ($F_{1.10}$=0.300, P=0.596, η_p^2=0.029) and density ($F_{1.10}$=1.994, P=0.188, η_p^2=0.166).

Distance covered running (8-13 km/h)

Analyses revealed a significant number of players x density interaction ($F_{1.10}$=12.795, P=0.005, η_p^2=0.561) for the distance covered in the 8-13 km/h zone. No significant main effect was found for number of players ($F_{1.10}$=0.619, P=0.450, η_p^2=0.058) and density ($F_{1.10}$=0.091, P=0.769, η_p^2=0.009). Further exploration showed significant differences between the scaled density – scaled numbers condition and both the standard density – scaled numbers (P=0.020) and scaled density – standard numbers (P=0.037) conditions. Significant differences were also found between the standard density – standard numbers and the scaled density – standard numbers (P=0.011) conditions.

Distance covered high-speed running (8-13 km/h)

Analyses of the distance covered in the 13-18 km/h zone per player per condition revealed a significant main effect for density ($F_{1.10}$=8.148, P=0.017, η_p^2=0.449) but no main effect was found for number of players ($F_{1.10}$=0.369, P=0.799, η_p^2=0.007). Also a significant number of players x density interaction ($F_{1.10}$=7.384, P=0.022, η_p^2=0.425) was found. Scaling the density lead to a decrease in the distance covered in the 15-20 km/h zone with 38.0 metres (95% CI [-67.661, -8.339]). Further exploration showed a significant difference between the standard density – standard numbers and both the scaled density – standard numbers (P=0.004) and standard density – scaled numbers (P=0.042) conditions.

Distance covered sprinting (>18km/h)

Analyses of the distance covered in the >18km/h zone per player per condition revealed a significant main effect for density ($F_{1.10}$=9.094, P=0.013, η_p^2=0.476) but no main effect was found for number of players ($F_{1.10}$=0.518, P=0.488, η_p^2=0.049). Also no numbers of players x density interaction ($F_{1.10}$=4.324, P=0.064, η_p^2=0.302) was found. Scaling the density lead to a decrease in the distance covered in the >20 km/h zone with 21.2 metres (95% CI [-10.333, -0.395]).

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite your child to be a part of a study titled "The influence of manipulating the number of players and game rules on the development of hockey skills of 14 and under hockey players". This study aims to examine the effect of a small sided games training intervention on the development of technical skills and decision making skills in field hockey. This project requires your child to perform a pre- and post-test and attend 16 training sessions. During the pre- and post-test, your child will perform multiple tests to measure his/her technical and decision making abilities including a full field competition match. During the training sessions your child will perform small sided games where game rules are manipulated but otherwise they play field hockey as they would during a typical competition match. There are risks associated with participation in this study and therefore all precautions will be taken to ensure the safety of your child.

CERTIFICATION BY SUBJECT

I, ____ (parent/guardians name)

of ____ (parent/guardians suburb)

certify that I am at least 18 years old and that I am voluntarily giving my consent for

my child ____ (participant/child's name)

to participate in a study titled: "The influence of manipulating the number of players and game rules on the development of hockey skills of 14 and under hockey players" being conducted by Victoria University researchers and Hockey Australia.

I, ____(participant/child's name) give assent to be involved in the study:

□ Yes

□ No

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by:

Ewout Timmerman, and that I freely consent to my child's participation involving the below mentioned procedures:

- Performing a pre- and post-test:
    - Passing test
    - Dribble test
    - Full field competition match
- Attending 16 small sided game training sessions.
- Monitoring of heart rate.
- Video recordings of the match-play. I understand that recording of the gameplay is needed for the analysis and I agree with the recordings of my child during gameplay:

□ Yes □ No

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw my child from this study at any time and that this withdrawal will not jeopardise me or my child in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher's

Professor Damian Farrow

Professor of Sport Science, Institute of Sport Exercise and Active Living

+61408445701

Ewout Timmerman, M.Sc

PhD student at the Institute of Sport Exercise and Active Living

+61415752780

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

INFORMATION TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

Your child is invited to participate in a research project entitled "The influence of manipulating the number of players and game rules on the development of hockey skills of 14 and under hockey players".

This project is being conducted by student researcher Ewout Timmerman as part of his PhD study at Victoria University under the supervision of Prof. Damian Farrow from the College of Sport and Exercise Science.

Project explanation

Your child is invited to participate in a research study that examines the influence of different player numbers in a small sided game training intervention on the development of technical and decision making of 14 and under hockey players. Your child will perform 16 training sessions. Before and after the training sessions your child will perform a passing test, a dribble test and a full field competition match (see below) to examine the effects of different player numbers in small sided games on the development of skill in field hockey. The 16 training sessions consists of playing small sided games where the rules of the game and number of players are manipulated. This study aims to provide information about the effect of different playing numbers in small sided games on the development of skills. This information will be used by coaches and trainers to improve the quality of training and therefore enhance the skill development of field hockey players in Victoria.

Passing test:

Your child will receive the ball from a ball-dispenser before pushing the ball as accurately and fast as possible into one of the targets. Your child will perform this six times per trial and will be asked to perform two trials. A passing time and an accuracy score will be recorded based on a target score.

Dribble test, single and dual task conditions:
During the single task condition, your child will run with the ball on the stick while finishing a course with 12 turns as fast as possible without letting the ball hit the cones or their feet. During the dual task condition, your child will be asked to name the letter which is shown by an experimenter while running with the ball through the same course as in the single task condition. Your child will perform both the single and dual task conditions twice; the average completion time of both trials will be used as an indication of dribble skill.

Full field competition match:

Your child will be asked to play a standard competition game that consists of two 25 minutes halves. Your child will be filmed when playing the match. These video recordings will be used to analyse game dynamics for individual and team characteristics.

Training sessions:

After performing the passing and dribble test and playing the full field game, your child will be asked to attend 16 training sessions over a period of 8 weeks. Each training session will start with a 10 minute warm-up, followed by four small sided games of 7.5 minutes with 2.5 minutes breaks between every game. The training session will finish with 10 minutes cooling down. During the small sided games, game rules and the number of players will be manipulated, for example some games will be a 3v3 and others 6v6. Your child will be filmed when playing these matches. These video recordings will be used to analyse game performance for individual and team characteristics. Your child will also be asked to wear a heart rate monitor. This information will be used as an indicator of the physical demands of the different small sided games.

What will my child be asked to do?

Your child will perform a pre- and post-test and will attend 16 training sessions. During the pre- and post-test your child will be asked to perform a passing test, a dribble test under single and dual task conditions and play a full field completion match. During the training sessions, your child will be asked to play four 7.5 minutes small sided games with 2.5 minutes break in between the games. Your child will be filmed when performing each small sided game and their heart rate will be monitored by wearing a standard heart rate monitor.

What will my child gain from participating?

Your child will be provided with an overview of his technical and decision making skill abilities. Also, your child will be provided with a summary of their game performance. This information could then be reviewed by yourself and your child to highlight the key skills that need to be practised at the junior development level. During the training intervention, your child has the opportunity to attend 16 training sessions that focuses on technical and decision making skills. During the training sessions, coaches will be present to guide the players and let them focus on improving their technical and decision making skills during the small sided games.

How will the information my child gives be used?

Firstly, the findings of this research will help coaches and trainers better understand the influence of small sided games on the development of technical and decision making skill in field hockey. The findings of this study will also provide coaches and trainers with guidelines about the influence of manipulating task constraints and number of players in small sided games. Thereby coaches are able to better match the training drills with their aims, what will be beneficial for skill development.

Secondly, the findings of this study will be presented in the form of a journal publication and a thesis. This means other coaches and scientists will be able to benefit from the knowledge gained from this study. Some of the recordings might be used at presentation for Hockey Australia and/or conferences to show differences between the small sided games. Please note that your child will not be named within this report and there is a low chance that someone outside of the team of researchers will be able to identify your child's results at any time during or following the study.

Thirdly, we would like to emphasize that the findings of this study will only be used for research purposes and will not be shared with Hockey Victoria for selection procedures. Game performance and test results will not have influence on selection or deselection for a representative squad of Hockey Victoria.

What are the potential risks of participating in this project?

While participating in this study, your child risks getting injured eg; soft tissue injury or getting hit by a ball as they would be during normal field hockey training or competition. All the necessary precautions to minimise the likelihood of this occurring will be taken. Similarly there are minor psychological and social risks in testing of this nature. To minimise these risk, the tests that might upset participants will be done on an individual base and results will not be reported to the participants self. If your child will be overwhelmed by any of the result that will come forward during participation in this study, you will be informed and advised and Dr Janet Young (ph +61 3 9919 4762) will be available as a professional counsellor through Victoria University who can be contacted for advice regarding counselling services.

How will this project be conducted?

If your child is willing to participate in this study, he/she will be invited to come to Maribyrnong Sports Academy (MSA), River st, Maribyrnong, where the passing test, the dribble and decision making test will be explained by one of the researchers. If everything is clear, the players will perform the testing and will then play a full field competition match. The training sessions will take place in the afternoon on the hockey pitch at MSA. After filming the match-play of your child during the small sided games, these recordings will be analysed by using a field hockey analysis program where variables will be entered into this program for team and individual analysis. The coding will be done by one of the researchers. After the 8 week training intervention, your child will again be invited to MSA where the passing test, dribble test and decision making test will be performed. The players will finish the study by playing a second full field competition match. Each participant will receive their individual results after testing via email.

Who is conducting the study?

Victoria University & Hockey Australia.

Professor Damian Farrow

Professor of Sport Science, Institute of Sport Exercise and Active Living

Telephone: 0408445701

Ewout Timmerman, M.Sc.

Phd Student at the Institute of Sport Exercise and Active Living

Telephone: 0415752780

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

	Normal game		Cage Hockey		Significant effects
	3v3	6v6	3v3	6v6	
Successful passes	8.10 (3.17)	5.14 (2.27)	8.83 (4.00)	6.06 (2.46)	PL ($F_{1.12}=33.0$, $p<0{,}001$, $\eta_p^2 = 0.73$) SSG ($F_{1.12}=2.3$, $p=0.153$, $\eta_p^2 = 0.16$) INT ($F_{1.12}=0.1$, $p=0.820$, $\eta_p^2 <0.01$)
Unsuccessful passes	2.65 (0.51)	1.64 (0.88)	3.40 (1.11)	2.15 (0.82)	PL ($F_{1.12}=29.4$, $p<0{,}001$, $\eta_p^2 = 0.71$) SSG ($F_{1.12}=7.1$, $p=0.021$, $\eta_p^2 = 0.37$) INT ($F_{1.12}=0.3$, $p=0.580$, $\eta_p^2 = 0.03$)
Total passes	10.75 (3.13)	6.78 (2.90)	12.24 (4.52)	8.21 (2.83)	PL ($F_{1.12}=51.5$, $p<0{,}001$, $\eta_p^2 = 0.81$) SSG ($F_{1.12}=4.8$, $p=0.048$, $\eta_p^2 = 0.29$) INT ($F_{1.12}<0.1$, $p=0.956$, $\eta_p^2 <0.01$)
% Successful passes	73.02 (11.74)	77.03 (10.87)	69.88 (9.80)	72.14 (11.39)	PL ($F_{1.12}=0.9$, $p=0.351$, $\eta_p^2 = 0.07$) SSG ($F_{1.12}=2.9$, $p=0.114$, $\eta_p^2 = 0.20$) INT ($F_{1.12}=0.1$, $p=0.751$, $\eta_p^2 = 0.01$)
Successful dribbles	2.81 (1.62)	1.15 (0.83)	2.66 (1.50)	1.39 (1.07)	PL ($F_{1.12}=19.2$, $p=0{,}001$, $\eta_p^2 = 0.62$) SSG ($F_{1.12}<0.1$, $p=0.873$, $\eta_p^2 <0.01$) INT ($F_{1.12}=0.6$, $p=0.454$, $\eta_p^2 = 0.05$)
Unsuccessful dribbles	1.61 (1.09)	0.78 (0.89)	1.53 (0.93)	0.76 (0.59)	PL ($F_{1.12}=13.0$, $p=0.004$, $\eta_p^2 = 0.52$) SSG ($F_{1.12}<0.1$, $p=0.855$, $\eta_p^2 <0.01$) INT ($F_{1.12}>0.1$, $p=0.870$, $\eta_p^2 <0.01$)
Total dribbles	4.42 (2.27)	1.92 (1.31)	4.19 (2.07)	2.15 (1.41)	PL ($F_{1.12}=28.4$, $p<0{,}001$, $\eta_p^2 = 0.70$) SSG ($F_{1.12}<0.1$, $p=0.999$, $\eta_p^2 <0.01$) INT ($F_{1.12}=0.8$, $p=0.390$, $\eta_p^2 = 0.06$)
% Successful dribbles	64.89 (18.83)	56.42 (28.49)	60.01 (18.38)	54.70 (29.54)	PL ($F_{1.12}=1.2$, $p=0.290$, $\eta_p^2 = 0.09$) SSG ($F_{1.12}=0.6$, $p=0.450$, $\eta_p^2 = 0.05$) INT ($F_{1.12}=0.1$, $p=0.740$, $\eta_p^2 = 0.01$)
Successful tackles	1.57 (1.11)	0.81 (0.52)	1.47 (0.80)	1.14 (0.96)	PL ($F_{1.12}=4.5$, $p=0.056$, $\eta_p^2 = 0.27$) SSG ($F_{1.12}=0.3$, $p=0.576$, $\eta_p^2 = 0.03$) INT ($F_{1.12}=1.6$, $p=0.237$, $\eta_p^2 = 0.11$)
Unsuccessful tackles	0.47 (0.36)	0.29 (0.28)	0.68 (0.61)	0.60 (0.33)	PL ($F_{1.12}=2.1$, $p=0.174$, $\eta_p^2 = 0.15$) SSG ($F_{1.12}=3.7$, $p=0.077$, $\eta_p^2 = 0.24$) INT ($F_{1.12}=0.4$, $p=0.564$, $\eta_p^2 = 0.03$)
Total tackles	2.04 (1.31)	1.10 (0.61)	2.15 (1.11)	1.75 (1.04)	PL ($F_{1.12}=4.5$, $p=0.056$, $\eta_p^2 = 0.27$) SSG ($F_{1.12}=2.7$, $p=0.128$, $\eta_p^2 = 0.18$) INT ($F_{1.12}=1.4$, $p=0.262$, $\eta_p^2 = 0.10$)
% Successful tackles	73.92 (20.36)	67.63 (28.94)	69.33 (20.51)	61.45 (27.28)	PL ($F_{1.12}=1.4$, $p=0.255$, $\eta_p^2 = 0.11$) SSG ($F_{1.12}=0.4$, $p=0.528$, $\eta_p^2 = 0.03$) INT ($F_{1.12}<0.1$, $p=0.886$, $\eta_p^2 <0.01$)
Interceptions	2.23 (1.36)	1.62 (1.22)	2.36 (1.20)	2.25 (1.34)	PL ($F_{1.12}=1.4$, $p=0.265$, $\eta_p^2 = 0.10$) SSG ($F_{1.12}=2.9$, $p=0.116$, $\eta_p^2 = 0.19$) INT ($F_{1.12}=2.1$, $p=0.172$, $\eta_p^2 = 0.15$)
Loss of ball possession	1.97 (0.70)	1.17 (0.93)	1.87 (1.29)	1.40 (0.95)	PL ($F_{1.12}=11.6$, $p=0.005$, $\eta_p^2 = 0.49$) SSG ($F_{1.12}=0.1$, $p=0.834$, $\eta_p^2 <0.01$) INT ($F_{1.12}=0.4$, $p=0.527$, $\eta_p^2 = 0.03$)
Low pressure	1.36 (0.64)	0.55 (0.36)	1.72 (0.81)	0.38 (0.37)	PL ($F_{1.12}=35.1$, $p<0{,}001$, $\eta_p^2 = 0.75$) SSG ($F_{1.12}=0.4$, $p=0.536$, $\eta_p^2 = 0.03$) INT ($F_{1.12}=2.3$, $p=0.159$, $\eta_p^2 = 0.16$)
Medium pressure	4.65 (0.74)	3.50 (1.14)	5.12 (1.81)	3.86 (0.94)	PL ($F_{1.12}=10.3$, $p=0.008$, $\eta_p^2 = 0.46$) SSG ($F_{1.12}=2.3$, $p=0.159$, $\eta_p^2 = 0.16$) INT ($F_{1.12}=0.1$, $p=0.808$, $\eta_p^2 = 0.01$)
High pressure	0.69 (0.46)	0.78 (0.65)	1.65 (0.93)	0.78 (0.57)	PL ($F_{1.12}=5.3$, $p=0.040$, $\eta_p^2 = 0.31$) SSG ($F_{1.12}=12.3$, $p=0.004$, $\eta_p^2 = 0.51$) INT ($F_{1.12}=5.2$, $p=0.042$, $\eta_p^2 = 0.30$)
Goals	1.12	0.42	1.35	0.38	PL ($F_{1.12}=44.4$, $p<0.001$, $\eta_p^2 = 0.79$)

	(0.61)	(0.43)	(0.93)	(0.56)	SSG ($F_{1.12}$=0.2, p=0.663, η_p^2 = 0.02) INT ($F_{1.12}$=1.3, p=0.286, η_p^2 = 0.09)
Scorings opportunity	0.90 (0.47)	0.30 (0.45)	1.05 (0.99)	0.41 (0.59)	PL ($F_{1.12}$=13.6, p=0.003, η_p^2 = 0.53) SSG ($F_{1.12}$=0.3, p=0.576, η_p^2 = 0.03) INT ($F_{1.12}$<0.1, p=0.869, η_p^2 <0.01)
Meters/Min	75.1 (8.8)	65.9 (11.8)	80.5 (13.2)	75.1 (15.1)	PL ($F_{1.12}$=7.2, p=0.020, η_p^2 = 0.38) SSG ($F_{1.12}$=12.0, p=0.005, η_p^2 = 0.50) INT ($F_{1.12}$=2.9, p=0.117, η_p^2 = 0.19)
% Walking (0-3 km/h)	13.4 (4.5)	17.8 (6.7)	14.8 (5.8)	17.7 (7.8)	PL ($F_{1.12}$=9.2, p=0.010, η_p^2 = 0.43) SSG ($F_{1.12}$=0.60, p=0.453, η_p^2 = 0.05) INT ($F_{1.12}$=0.71, p=0.415, η_p^2 = 0.06)
% Jogging (3-8 km/h)	50.1 (4.5)	54.4 (6.0)	49.4 (3.9)	52.5 (6.5)	PL ($F_{1.12}$=15.0, p=0.002, η_p^2 = 0.56) SSG ($F_{1.12}$=3.03, p=0.107, η_p^2 = 0.20) INT ($F_{1.12}$=0.51, p=0.489, η_p^2 = 0.04)
% Running (8-13 km/h)	25.5 (3.8)	20.8 (4.4)	26.3 (5.0)	22.2 (5.1)	PL ($F_{1.12}$=29.3, p<0.001, η_p^2 = 0.71) SSG ($F_{1.12}$=3.4, p=0.091, η_p^2 = 0.22) INT ($F_{1.12}$=0.2, p=0.700, η_p^2 = 0.01)
% High-speed running (13-18 km/h)	9.9 (3.0)	6.5 (3.1)	8.8 (3.2)	6.9 (3.1)	PL ($F_{1.12}$=18.4, p=0.001, η_p^2 = 0.61) SSG ($F_{1.12}$=0.6, p=0.472, η_p^2 = 0.04) INT ($F_{1.12}$=4.3, p=0.061, η_p^2 = 0.26)
% Sprinting (>18 km/h)	1.0 (1.1)	0.6 (0.7)	0.8 (1.0)	0.7 (1.1)	PL ($F_{1.12}$=2.4, p=0.151, η_p^2 = 0.16) SSG ($F_{1.12}$=0.3, p=0.590, η_p^2 = 0.03) INT ($F_{1.12}$=0.2, p=0.644, η_p^2 = 0.02)
RPE	4.8 (0.8)	5.4 (1.1)	5.1 (0.8)	5.3 (1.0)	PL ($F_{1.12}$=3.1, p=0.102, η_p^2 = 0.21) SSG ($F_{1.12}$=0.6, p=0.472, η_p^2 = 0.04) INT ($F_{1.12}$=1.8, p=0.204, η_p^2 = 0.13)

	Normal game		Possession		Significant effects
	3v3	6v6	3v3	6v6	
Successful passes	8.10 (3.17)	5.14 (2.27)	12.36 (3.15)	7.83 (3.70)	PL ($F_{1.12}$=33.6, p<0,001, η_p^2 = 0.74) SSG ($F_{1.12}$=34.8, p<0.001, η_p^2 = 0.74) INT ($F_{1.12}$=2.4, p=0.141, η_p^2 = 0.17)
Unsuccessful passes	2.65 (0.51)	1.64 (0.88)	4.52 (0.97)	2.46 (0.90)	PL ($F_{1.12}$=38.3, p<0,001, η_p^2 = 0.76) SSG ($F_{1.12}$=34.9, p<0.001, η_p^2 = 0.74) INT ($F_{1.12}$=6.2, p=0.028, η_p^2 = 0.34)
Total passes	10.75 (3.13)	6.78 (2.90)	16.88 (2.89)	10.29 (3.75)	PL ($F_{1.12}$=53.2, p<0,001, η_p^2 = 0.82) SSG ($F_{1.12}$=73.0, p<0.001, η_p^2 = 0.86) INT ($F_{1.12}$=5.6, p=0.036, η_p^2 = 0.32)
% Successful passes	73.02 (11.74)	77.03 (10.87)	72.37 (7.90)	73.96 (12.28)	PL ($F_{1.12}$=0.76, p=0.400, η_p^2 = 0.06) SG ($F_{1.12}$=0.56, p=0.468, η_p^2 = 0.05) INT ($F_{1.12}$=0.2, p=0.692, η_p^2 = 0.01)
Successful dribbles	2.81 (1.62)	1.15 (0.83)	1.73 (1.08)	0.93 (0.87)	PL ($F_{1.12}$=17.5, p=0,001, η_p^2 = 0.60) SSG ($F_{1.12}$=5.4, p=0.038, η_p^2 = 0.31) INT ($F_{1.12}$=3.2, p=0.099, η_p^2 = 0.21)
Unsuccessful dribbles	1.61 (1.09)	0.78 (0.89)	0.53 (0.68)	0.19 (0.38)	PL ($F_{1.12}$=13.5, p=0.003, η_p^2 = 0.53) SSG ($F_{1.12}$=8.8, p=0.012, η_p^2 = 0.42) INT ($F_{1.12}$=2.0, p=0.183, η_p^2 = 0.14)
Total dribbles	4.42 (2.27)	1.92 (1.31)	2.26 (1.57)	1.12 (0.99)	PL ($F_{1.12}$=30.0, p<0,001, η_p^2 = 0.71) SSG ($F_{1.12}$=8.3, p=0.014, η_p^2 = 0.41) INT ($F_{1.12}$=5.2, p=0.041, η_p^2 = 0.30)
% Successful dribbles	64.89 (18.83)	56.42 (28.49)	72.24 (29.53)	72.66 (37.57)	PL ($F_{1.12}$=0.8, p=0.407, η_p^2 = 0.06) SSG ($F_{1.12}$=2.2, p=0.168, η_p^2 = 0.15) INT ($F_{1.12}$=0.6, p=0.456, η_p^2 = 0.05)
Successful tackles	1.57 (1.11)	0.81 (0.52)	0.90 (0.68)	0.34 (0.50)	PL ($F_{1.12}$=12.0, p=0.005, η_p^2 = 0.50) SSG ($F_{1.12}$=6.8, p=0.023, η_p^2 = 0.36) INT ($F_{1.12}$=0.3, p=0.590, η_p^2 = 0.03)
Unsuccessful tackles	0.47 (0.36)	0.29 (0.28)	0.28 (0.34)	0.25 (0.37)	PL ($F_{1.12}$=1.4, p=0.265, η_p^2 = 0.10) SSG ($F_{1.12}$=1.5, p=0.248, η_p^2 = 0.11) INT ($F_{1.12}$=1.0, p=0.335, η_p^2 = 0.08)
Total tackles	2.04 (1.31)	1.10 (0.61)	1.18 (0.70)	0.59 (0.68)	PL ($F_{1.12}$=9.3, p=0.010, η_p^2 = 0.44) SSG ($F_{1.12}$=7.5, p=0.018, η_p^2 = 0.39) INT ($F_{1.12}$=1.0, p=0.342, η_p^2 = 0.08)
% Successful tackles	73.92 (20.36)	67.63 (28.94)	68.76 (31.27)	35.54 (44.60)	PL ($F_{1.12}$=12.3, p=0.004, η_p^2 = 0.51) SSG ($F_{1.12}$=4.3, p=0.061, η_p^2 = 0.26) INT ($F_{1.12}$=1.7, p=0.217, η_p^2 = 0.12)
Interceptions	2.23 (1.36)	1.62 (1.22)	2.86 (1.66)	1.98 (1.35)	PL ($F_{1.12}$=5.7, p=0.034, η_p^2 = 0.32) SSG ($F_{1.12}$=1.6, p=0.236, η_p^2 = 0.12) INT ($F_{1.12}$=0.2, p=0.630, η_p^2 = 0.02)
Loss of ball possession	1.97 (0.70)	1.17 (0.93)	1.92 (0.83)	1.25 (0.80)	PL ($F_{1.12}$=16.6, p=0.002, η_p^2 = 0.58) SSG ($F_{1.12}$<0.1, p=0.951, η_p^2 <0.01) INT ($F_{1.12}$=0.1, p=0.770, η_p^2 <0.01)
Low pressure	1.36 (0.64)	0.55 (0.36)	1.98 (1.02)	0.38 (0.57)	PL ($F_{1.12}$=42.2, p<0,001, η_p^2 = 0.78) SSG ($F_{1.12}$=2.4, p=0.144, η_p^2 = 0.17) INT ($F_{1.12}$=5.5, p=0.037, η_p^2 = 0.31)
Medium pressure	4.65 (0.74)	3.50 (1.14)	7.75 (1.75)	4.64 (2.44)	PL ($F_{1.12}$=27.9, p<0,001, η_p^2 = 0.70) SSG ($F_{1.12}$=21.6, p=0.001, η_p^2 = 0.64) INT ($F_{1.12}$=7.7, p=0.017, η_p^2 = 0.39)
High pressure	0.69 (0.46)	0.78 (0.65)	2.02 (0.85)	1.11 (0.61)	PL ($F_{1.12}$=4.9, p=0.048, η_p^2 = 0.29) SSG ($F_{1.12}$=14.6, p=0.002, η_p^2 = 0.55)

					INT ($F_{1.12}$=13.8, p=0.003, η_p^2 = 0.54)
Meters/Min	75.1 (8.8)	65.9 (11.8)	83.5 (7.5)	77.2 (15.1)	PL ($F_{1.12}$=8.4 p=0.014, η_p^2 = 0.41) SSG ($F_{1.12}$=21.1, p=0.001, η_p^2 = 0.64) INT ($F_{1.12}$=0.9, p=0.360, η_p^2 = 0.07)
% Walking (0-3 km/h)	13.4 (4.5)	17.8 (6.7)	14.3 (5.5)	17.1 (7.8)	PL ($F_{1.12}$=8.7, p=0.012, η_p^2 = 0.42) SSG ($F_{1.12}$<0.1, p=0.931, η_p^2 <0.01) INT ($F_{1.12}$=1.3, p=0.283, η_p^2 = 0.10)
% Jogging (3-8 km/h)	50.1 (4.5)	54.4 (6.0)	51.6 (5.4)	54.5 (4.5)	PL ($F_{1.12}$=12.0, p=0.005, η_p^2 = 0.50) SSG ($F_{1.12}$=1.0, p=0.330, η_p^2 = 0.08) INT ($F_{1.12}$=0.8, p=0.390, η_p^2 = 0.06)
% Running (8-13 km/h)	25.5 (3.8)	20.8 (4.4)	27.8 (3.9)	22.7 (7.3)	PL ($F_{1.12}$=13.7, p=0.003, η_p^2 = 0.53) SSG ($F_{1.12}$=4.6, p=0.053, η_p^2 = 0.28) INT ($F_{1.12}$<0.1, p=0.835, η_p^2 <0.01)
% High-speed running (13-18 km/h)	9.9 (3.0)	6.5 (3.1)	6.0 (3.4)	5.4 (2.9)	PL ($F_{1.12}$=26.8, p<0,001, η_p^2 = 0.69) SSG ($F_{1.12}$=21.1, p=0.001, η_p^2 = 0.64) INT ($F_{1.12}$=9.1, p=0.011, η_p^2 = 0.43)
% Sprinting (>18 km/h)	1.0 (1.1)	0.6 (0.7)	0.3 (0.5)	0.3 (0.6)	PL ($F_{1.12}$=1.2, p=0.290, η_p^2 = 0.09) SSG ($F_{1.12}$=6.0, p=0.031, η_p^2 = 0.33) INT ($F_{1.12}$=2.4, p=0.144, η_p^2 = 0.17)
RPE	4.8 (0.8)	5.4 (1.1)	5.4 (1.3)	5.0 (0.8)	PL ($F_{1.12}$=0.6, p=0.467, η_p^2 = 0.05) SSG ($F_{1.12}$=0.1, p=0.768, η_p^2 = 0.01) INT ($F_{1.12}$=7.3, p=0.019, η_p^2 = 0.38)

	Normal game		Two goals		Significant effects
	3v3	6v6	3v3	6v6	
Successful passes	8.10 (3.17)	5.14 (2.27)	8.70 (3.08)	5.62 (2.38)	PL ($F_{1.12}$=27.3, p<0,001, η_p^2 = 0.70) SSG ($F_{1.12}$=2.5, p=0.140, η_p^2 = 0.17) INT ($F_{1.12}$<0.1, p=0.899, η_p^2 <0.01)
Unsuccessful passes	2.65 (0.51)	1.64 (0.88)	2.66 (1.07)	1.91 (1.19)	PL ($F_{1.12}$=23.7, p<0,001, η_p^2 = 0.66) SSG ($F_{1.12}$=0.3, p=0.581, η_p^2 = 0.03) INT ($F_{1.12}$=0.3, p=0.618, η_p^2 = 0.02)
Total passes	10.75 (3.13)	6.78 (2.90)	11.35 (3.30)	7.53 (1.99)	PL ($F_{1.12}$=53.2 p<0,001, η_p^2 = 0.82) SSG ($F_{1.12}$=4.0, p=0.068, η_p^2 = 0.25) INT ($F_{1.12}$<0.1, p=0.882, η_p^2 <0.01)
% Successful passes	73.02 (11.74)	77.03 (10.87)	75.43 (10.99)	71.75 (18.58)	PL ($F_{1.12}$<0.1, p=0.953, η_p^2 <0.01) SSG ($F_{1.12}$=0.2, p=0.658, η_p^2 = 0.02) INT ($F_{1.12}$=1.1, p=0.320, η_p^2 = 0.08)
Successful dribbles	2.81 (1.62)	1.15 (0.83)	3.46 (1.94)	1.54 (1.26)	PL ($F_{1.12}$=21.1, p=0,001, η_p^2 = 0.64) SSG ($F_{1.12}$=2.4, p=0.148, η_p^2 = 0.17) INT ($F_{1.12}$=0.2, p=0.686, η_p^2 = 0.02)
Unsuccessful dribbles	1.61 (1.09)	0.78 (0.89)	1.41 (1.23)	0.74 (0.85)	PL ($F_{1.12}$=10.0, p=0.008, η_p^2 = 0.46) SSG ($F_{1.12}$=0.8, p=0.380, η_p^2 = 0.07) INT ($F_{1.12}$=0.3, p=0.584, η_p^2 = 0.03)
Total dribbles	4.42 (2.27)	1.92 (1.31)	4.87 (2.49)	2.29 (1.69)	PL ($F_{1.12}$=33.0, p<0,001, η_p^2 = 0.73) SSG ($F_{1.12}$=1.2, p=0.296, η_p^2 = 0.09) INT ($F_{1.12}$<0.1, p=0.898, η_p^2 <0.01)
% Successful dribbles	64.89 (18.83)	56.42 (28.49)	72.54 (23.60)	63.20 (27.32)	PL ($F_{1.12}$=1.4, p=0.260, η_p^2 = 0.10) SSG ($F_{1.12}$=2.0, p=0.184, η_p^2 = 0.14) INT ($F_{1.12}$<0.1, p=0.927, η_p^2 >0.01)
Successful tackles	1.57 (1.11)	0.81 (0.52)	1.27 (0.67)	0.82 (0.79)	PL ($F_{1.12}$=11.9, p=0.005, η_p^2 = 0.50) SSG ($F_{1.12}$=0.8, p=0.401, η_p^2 = 0.06) INT ($F_{1.12}$=0.4, p=0.533, η_p^2 = 0.03)
Unsuccessful tackles	0.47 (0.36)	0.29 (0.28)	0.64 (0.51)	0.24 (0.30)	PL ($F_{1.12}$=12.3, p=0.004, η_p^2 = 0.51) SSG ($F_{1.12}$=0.3, p=0.635, η_p^2 = 0.02) INT ($F_{1.12}$=1.5, p=0.248, η_p^2 = 0.11)
Total tackles	2.04 (1.31)	1.10 (0.61)	1.91 (0.82)	1.06 (0.72)	PL ($F_{1.12}$=19.4, p=0.001, η_p^2 = 0.62) SSG ($F_{1.12}$=0.2, p=0.700, η_p^2 = 0.01) INT ($F_{1.12}$<0.1, p=0.865, η_p^2 <0.01)
% Successful tackles	73.92 (20.36)	67.63 (28.94)	67.34 (27.39)	64.30 (41.96)	PL ($F_{1.12}$=0.3, p=0.604, η_p^2 = 0.02) SSG ($F_{1.12}$=0.4, p=0.551, η_p^2 = 0.03) INT ($F_{1.12}$<0.1, p=0.848, η_p^2 <0.01)
Interceptions	2.23 (1.36)	1.62 (1.22)	2.45 (1.33)	1.99 (1.07)	PL ($F_{1.12}$=3.4, p=0.091, η_p^2 = 0.22) SSG ($F_{1.12}$=0.8, p=0.376, η_p^2 = 0.07) INT ($F_{1.12}$=0.1, p=0.774, η_p^2 = 0.01)
Loss of ball possession	1.97 (0.70)	1.17 (0.93)	1.77 (0.98)	1.26 (0.88)	PL ($F_{1.12}$=11.3, p=0.006, η_p^2 = 0.49) SSG ($F_{1.12}$=0.1, p=0.800, η_p^2 = 0.01) INT ($F_{1.12}$=0.5, p=0.517, η_p^2 = 0.04)
Low pressure	1.36 (0.64)	0.55 (0.36)	1.10 (0.45)	0.99 (0.67)	PL ($F_{1.12}$=11.7, p=0.005, η_p^2 = 0.49) SSG ($F_{1.12}$=0.4, p=0.544, η_p^2 = 0.03) INT ($F_{1.12}$=6.5, p=0.026, η_p^2 = 0.35)

Medium pressure	4.65 (0.74)	3.50 (1.14)	5.30 (1.92)	3.49 (1.49)	PL ($F_{1.12}$=15.2, p=0.002, η_p^2 = 0.56) SSG ($F_{1.12}$=0.6, p=0.438, η_p^2 = 0.05) INT ($F_{1.12}$=0.7, p=0.407, η_p^2 = 0.06)
High pressure	0.69 (0.46)	0.78 (0.65)	1.05 (0.60)	0.91 (0.77)	PL ($F_{1.12}$<0.1, p=0.898, η_p^2 <0.01) SSG ($F_{1.12}$=1.9, p=0.192, η_p^2 = 0.14) INT ($F_{1.12}$=0.8, p=0.403, η_p^2 = 0.06)
Goals	1.12 (0.61)	0.42 (0.43)	2.20 (1.51)	0.57 (0.53)	PL ($F_{1.12}$=28.2, p<0,001, η_p^2 = 0.70) SSG ($F_{1.12}$=5.5, p=0.037, η_p^2 = 0.32) INT ($F_{1.12}$=6.3, p=0.028, η_p^2 = 0.34)
Scorings opportunity	0.90 (0.47)	0.30 (0.45)	1.25 (1.24)	0.15 (0.27)	PL ($F_{1.12}$=24.3, p<0,001, η_p^2 = 0.67) SSG ($F_{1.12}$=0.4, p=0.517, η_p^2 = 0.04) INT ($F_{1.12}$=1.6, p=0.235, η_p^2 = 0.12)
Meters/Min	75.1 (8.8)	65.9 (11.8)	87.43 (9.9)	76.0 (11.9)	PL ($F_{1.12}$=23.0, p<0,001, η_p^2 = 0.66) SSG ($F_{1.12}$=46.3 p<0,001, η_p^2 = 0.79) INT ($F_{1.12}$=0.7, p=0.431, η_p^2 = 0.05)
% Walking (0-3 km/h)	13.4 (4.5)	17.8 (6.7)	13.5 (4.9)	15.6 (5.9)	PL ($F_{1.12}$=8.9, p=0.011, η_p^2 = 0.43) SSG ($F_{1.12}$=4.2, p=0.063, η_p^2 = 0.26) INT ($F_{1.12}$=4.0, p=0.069, η_p^2 = 0.25)
% Jogging (3-8 km/h)	50.1 (4.5)	54.4 (6.0)	50.8 (4.4)	52.9 (5.5)	PL ($F_{1.12}$=8.8, p=0.012, η_p^2 = 0.42) SSG ($F_{1.12}$=0.3, p=0.608, η_p^2 = 0.02) INT ($F_{1.12}$=1.4, p=0.264, η_p^2 = 0.10)
% Running (8-13 km/h)	25.5 (3.8)	20.8 (4.4)	27.3 (4.6)	22.7 (4.8)	PL ($F_{1.12}$=15.8 p=0.002, η_p^2 = 0.57) SSG ($F_{1.12}$=5.9, p=0.032, η_p^2 = 0.33) INT ($F_{1.12}$>0.1, p=0.924, η_p^2 <0.01)
% High-speed running (13-18 km/h)	9.9 (3.0)	6.5 (3.1)	7.9 (2.5)	7.8 (3.1)	PL ($F_{1.12}$=11.6, p=0.005, η_p^2 = 0.49) SSG ($F_{1.12}$=0.3, p=0.584, η_p^2 = 0.03) INT ($F_{1.12}$=6.5, p=0.025, η_p^2 = 0.35)
% Sprinting (>18 km/h)	1.0 (1.1)	0.6 (0.7)	0.5 (0.5)	1.0 (1.2)	PL ($F_{1.12}$<0.1, p=0.871, η_p^2 <0.01) SSG ($F_{1.12}$=0.5, p=0.474, η_p^2 = 0.04) INT ($F_{1.12}$=4.2, p=0.064, η_p^2 = 0.26)
RPE	4.8 (0.8)	5.4 (1.1)	5.2 (0.9)	4.8 (0.6)	PL ($F_{1.12}$=1.0, p=0.334, η_p^2 = 0.08) SSG ($F_{1.12}$=0.1, p=0.806, η_p^2 = 0.01) INT ($F_{1.12}$=6.9, p=0.022, η_p^2 = 0.36)