UNIVERSITEIT
GENT

FACULTY OF MEDICINE AND HEALTH SCIENCES
DEPARTMENT OF MOVEMENT AND SPORTS SCIENCES

The Flemish Sports Compass

From sports orientation to elite performance prediction

Johan Pion

Thesis submitted in fulfillment of the requirements for the degree of
Doctor in Health Sciences

Gent 2015

Supervisor:

Prof. dr. Matthieu Lenoir (Ghent University)

Co-supervisor:

Prof. dr. Veerle Segers (Ghent University)

Chairman of the examination board:

Prof. dr. Johan Van de Voorde (Ghent University)

Examination board:

Prof. dr. Marije Elferink-Gemser (University of Groningen, Netherlands)
Prof. dr. Christophe Delecluse (KU Leuven)
Prof. dr. Luc Vanden Bossche (Ghent University)
Prof. dr. Dirk De Clercq (Ghent University)
Prof. dr. Wim Derave (Ghent University)

Printed by University Press, Zelzate (http://www.universitypress.be)
Cover design: Geert Van Belleghem

ISBN:

TABLE OF CONTENTS

TABLES

FIGURES

DANKWOORD

Het werk dat u in handen hebt is naast de samenvatting van 8 jaar wetenschappelijk onderzoek naar talent in de sport ook nog een samenbundeling van een leven lang ervaring en kennis opdoen in de praktijk. De sport en in het bijzonder de gymnastiek hebben mijn doen en laten bepaald. Voor wie mij kent, is spelen mijn leven en een ruim begrip dat gaat van rummikub tot artificiële neurale netwerken en van flikflak tot wereldbeker finales tumbling. Maar nu de speelvogel, ooit sportman en gepassioneerd trainer, een sport scientist geworden is, groeit het besef dat spelen een serieuze aangelegenheid is. Met het diploma dat ik net behaald heb zal je het overal ter wereld ver schoppen, jammer genoeg klinkt de titel ‘sport-saaien-tist’ in Antwerpen iets minder aantrekkelijk als elders.

Als ik mij afvraag hoe het zo ver is kunnen komen, dat ik hier met dit gekke hoofddeksel (barretje) mag staan pronken, ben ik er van overtuigd dat de combinatie werk en vrije tijd mij dit uniek moment geboden heeft. Mijn leven tussen bureau en turnzaal begon in het turnzaaltje aan de Oude God toen Gert, Luc en Benny, en een ploeg begaafde jonge gymnasten een groot deel van mijn vrije tijd opeisten. Die periode werd na meer dan twee decennia afgerond op de finale tijdens de wereldbekerwedstrijd tumbling in Oostende, toen An besloot om haar talenten te verzilveren bij ‘Cirque Du Soleil’. De praktijk, maar uiteraard ook mijn professionele carrière waarbij ik mij heb kunnen ontplooien in de sportsector, gaf de aanzet tot dit werk. Het mag dus duidelijk zijn dat de ervaring in de sport gezorgd heeft voor de extra troeven. Toen de Vakgroep Bewegings- en Sportwetenschappen startte met het Vlaams Sportkompas, besloot ik om een zekerheid opzij te zetten voor een uitdaging, waar ik met alle vertrouwen tegenaan keek omdat tests en metingen steeds centraal stonden tijdens de periode voor ik in Gent werkte. Het was geen foute gok, ook al kostte het veel moeite om de sceptici te overtuigen.

Het is nu tijd om de mensen te bedanken die mij de kans geboden hebben om dit werk af te maken. Eerst en vooral mijn promotor Matthieu die de touwtjes in handen heeft van een sterk team. Matthieu is bijzonder, en ik ben uitermate trots op mijn promotor die mij zeer veel heeft bijgeleerd. Het is trouwens niet zo evident, maar hij is er toch maar in geslaagd om een oude aap nog truukjes te leren. Een onwaarschijnlijke prestatie is dat hij met al zijn talent-medewerkers een vijftigtal peer reviewed artikels heeft geschreven. Met de trilogie Pieter, Dieter en Johan slaagt hij er dit jaar zelfs in om drie doctors in de gezondheidswetenschappen af te leveren, samen hebben ze meer dan 20 keer ‘et al’ achter hun naam staan. Bedankt, dat jij de bezieler was van ons team. Ook al wist je met momenten letterlijk en figuurlijk geen blijf met ons, je hebt steeds een oplossing gevonden om al onze talenten te laten openbloeien. De container achter het gebouw was dan ook blijkbaar de enige oplossing. Bedankt Matthieu, voor uw steun en alle slapeloze nachten om oplossingen te zoeken voor alle contractenverlengingen.

Wie uiteraard mee op de eerste rij moet staan is mijn co-promotor Veerle, die mij met veel enthousiasme het pad van de ‘data mining’ heeft opgestuurd. Haar opbouwende kritiek heeft geleid tot dit proefschrift. Veerle, het is steeds leuk om met jou samen te werken en ik hoop dat dit nog even mag blijven duren. Bedankt voor alle kleine dingen die het werk aangenaam maakten.

Naast mijn promotor en co-promotor hebben de leden van de leescommissie een groot aandeel in de uiteindelijke inhoud van dit werk. Hun gefundeerde opmerkingen, vragen en bedenkingen hebben mij aangezet om de tekst nog iets beter verteerbaar uit te schrijven. Daarom dank ik Voorzitter Prof dr. Johan Van de Voorde, Prof. dr. Christophe Delecluse, Prof. dr. Luc Vanden Bossche, Prof. dr. Wim Derave en Prof. dr. Dirk De Clercq voor hun interesse en hun gefundeerde opmerkingen. Ik richt hierbij ook een woord van dank tot Renaat en Roel die mee de eerste impulsen gaven aan het Vlaams Sportkompas. Many thanks to Prof. dr. Marije Elferink-Gemser znd Prof dr. Andreas Hohmann for their nice collaboration and discussions on talent in sports.

Heel veel lof gaat uiteraard ook naar mijn collega's die meewerkten aan het Vlaams Sportkompas. Tijdens de periode van data verzamelen in de basisscholen, de sportclubs en de topsportscholen hielpen we elkaar dag in dag uit en we keken nooit op een uurtje meer (of minder) werken. Barbara en Joric stonden mee aan de wieg van het sportkompas. Ze staan nu samen aan een andere wieg en ik kan mij hierbij voorstellen hoe leuk ze het vinden om elke dag opnieuw vroeg op te staan. Zij legden mee de fundamenten van dit werk, terwijl Stijn in diezelfde periode ’s avonds alle handbalclubs in Vlaanderen bezocht en meer dan één keer een handje toestak. Met de verhuis naar de containers, werd het talent team 2.0 met Dieter en Job versterkt. De humor en meer bepaald het onderling pesten werd als kunstvorm verheven. De gekke situaties volgden elkaar op en onze vriendschap en appreciatie werd hierdoor zeer hecht. Dieter is no-nonsense, hij gaf onze testdagen nog meer structuur en rendement, terwijl hij in alle stilte een voetbalbijbel produceerde waar nog lang over gesproken zal worden. Zijn passie voor het voetbal heeft zelfs de meest fanatieke gymnast meer dan één keer aangespoord om toch mee te gaan supporteren voor de rode duivels.

De herinnering aan Job’s eerste dag in onze container is niet meer uit te wissen. Zijn uitspraken en sierlijke bewegingen zijn legendarisch. Weinigen hebben het lef van deze ‘drakendoder’ die vanaf de eerste minuut verkondigde dat hij zijn doctoraat eventjes ging afwerken om vervolgens professor te worden in Australië. Job, ik kom eraan want we hebben toen ook afgesproken dat we elkaar terug zouden ontmoeten onder de brug in Sydney. Zet de koffie maar klaar, maar niet ‘the one from the basement’ hé.

Toen Gijs talent team 3.0 vervoegde, zaten we aan onze top en bestond onze groep al 4 uit talent doctors of zukkentwuk. Gijs en ik waren vier handen op één buyck en we waren vastbesloten om twee doctoraten met zijn tweeën af te werken, want dat zou makkelijker zijn dan elk eentje alleen. Het plan hangt nog steeds op de kast. De transfer naar Zulte Waregem heeft roet in het eten gegooid,. Ik blijf hem echter opvolgen, al was het maar omdat hij nog wat leeggoed van de voorbije feestjes heeft staan.

Talent team 4.0 staat klaar met Mireille en Lee die het sportkompas nog meer gaan verfijnen. Uiteraard ben ik bereid om voor de nieuwe collega's in de bres te springen en er een mooi vervolg aan te breien en hiervoor reken ik uiteraard ook op Kristof.

Het Hilo is natuurlijk meer dan de kleine kring van talentenjagers. De collega's die ik elke dag tegen het lijf loop zijn o.a. Frederic, Linus, Pieter, Mireille, Inge, Tine, Laura, Jan, Audrey, Sanne, Pieter, Lennert, Sien, Ine, Philippe, Sam, Bas, Sofie, Bert, Jasmien, Margot, An, Ann, Davy, Joeri, Nadia, Isabelle, Petra, Erwin, Vera... Door bij jullie te blijven plakken heb ik dikwijls een trein gemist, en avonden thuis moeten doorwerken omdat er die dag nog niet voldende gepresteerd was. Bedankt collega's dat je met mijn grappen kon lachen of toch deed alsof.

Uiteraard is er een speciaal woordje voor mijn goede vriend Raf met wie ik uren heb overlegd hoe we onze gymnasten beter konden maken. De besprekingen begonnen bij de ontbijttafel op zondag en liepen soms door tot na het avondeten. De voorbije maanden gingen de gesprekken over talent, voeding en filemaker en af en toe gaf je zonder het te weten de beslissende voorzet voor een paper of een presentatie. Nu Sam voor de drukte in huis zorgt, heb je jouw handen vol en vinden we toch nog de tijd om bij te kletsen. Je weet Raf dat mocht je ooit willen starten met een doctoraat dat je dan op mij kan rekenen.

Ondanks de passie voor mijn werk, heb ik ook nog een druk leven naast de sport. Chrisje's netwerk is gigantisch en de agenda thuis staat constant volgeboekt. Het is het soort planning waar ik weinig inspraak heb, met telkens wel ergens een weekend met vrienden of familie of een barbecue of een feestje. De uitzondering is de wijnclub die bovenaan de agenda staat, ook al is er maar één bijeenkomst per maand.
De vele bezoekjes aan mijn ouders hebben broers en zussen de laatste tijd nog dichter bij elkaar gebracht en het is de kern van de grotere familiekring, het zijn er ook weeral een honderdtal, die ik in het hart draag omdat we zo goed samen opschieten. De familie Pion, Vermeiren en Jagers zijn op en top levensgenieters die heel veel geven om elkaar. Het beste bewijs kan je dagelijks ervaren in de Speeltuinlaan waar iedereen in de omgeving van den bompa is blijven hangen. Het kan ook moeilijk anders, want hij lost alle problemen op en het is vooral een plezier om nooit vooraf te weten of we thuis of bij tante Marleen, onze Raf of Johnny blijven eten. Bovendien is den bompa het prototype van de betere beweger. Hij heeft zijn gaven omgezet in talent en geniet er nog elke zondag van om te zeilen met een laser. Op je 86e is dit een prachtprestatie die weinigen jou nadoen.

De laatste woordjes wil ik voorbehouden voor Raf, Tim en Chrisje. Mijn gezin, waar iedereen barst van talent. De sport, muziek, techniek en kunst zijn ons op het lijf gegoten en als we ergens voor gaan, dan is het ook ineens met heel veel passie. Daarom ben ik ook zo trots op mijn jongens. Tenslotte, liefste schat, voor je mij zelf de vraag stelt, of het 'DAT' nu is? Moet ik jou voor de zoveelste keer ontgoochelen, want de allerbelangrijkste doelstelling van dit werk, is eigenlijk het feestje waar iedereen nu zit op te wachten. Dat draag ik op aan jou, omdat je er genoeg hebt voor opzij gezet.

SUMMARY

The road from beginner to sports champion is a long and unpredictable one. Therefore, choosing a sport that fits their individual characteristics is essential for children to keep them involved in sports. The Flemish Sports Compass is a generic test battery designed to advise children in their sports choice. The test battery includes anthropometric, physical and motor performance measurements and it has the special quality that, in addition to talent detection and talent orientation, it also enhances various derivative test batteries for talent identification. The Flemish Sports Compass consists of field tests appliable in both elementary schools children and in Flemish elite sport schools. On the one hand it is possible to discriminate between different performance levels and on the other this test battery has te ability to detect sport-specific characteristics of an individual.

First part of this doctoral dissertation consists of two introductory chapters. The first chapter provides an overview of definitions, theoretical talent models and practical talent systems. The second chapter explains the rationale and the design of the Flemish Sports Compass and displays the preliminary studies for designing the Flemish Sports Compass.

In the second part of this dissertation, six original studies are reported. The first study highlights the potential of the Flemish Sports Compass for primary school children. In this study the differences between the sport specific profiles are less pronounced than in the second and the third study, which measured respectively the students of the Flemish elite sport schools and promising athletes of different sports federations. The first three studies indicated that the generic test battery can be deployed on beginners (talent detection) as well as elite athletes (talent identification). The fourth study, with increased specificity, indicates that the generic tests of the Flemish Sports Compass also are able to distinguish between medallists in international competitions and sub-elite volleyball players. The talent characteristics measured by the Flemish Sports Compass are not only good at predicting and identifying elite level, they also predict attrition in sport. In the fifth study, survival analysis was applied. Parallel to the methods used in medical science where examining the outcome of medication on the participants life expectations is the main goal, survival chances of athletes were calculated in our fifth study. The last study indicated the importance of predictive analytics of a generic test battery. It was shown that artificial neural networks reduce the risk of missing gifted athletes, when selecting the high potential athletes and how the cost of talent development can be reduced without losing talents.

In the third part of this dissertation results are discussed and critical reflections and recommendations are given. The different studies provide opportunities to develop a specific talent system for a small country. Flanders' disadvantage is, that it is hard to compete with giant nations such as China, Russia and the United States. However, the disadvantage of being small is an advantage at the same time. Smallness reduces the

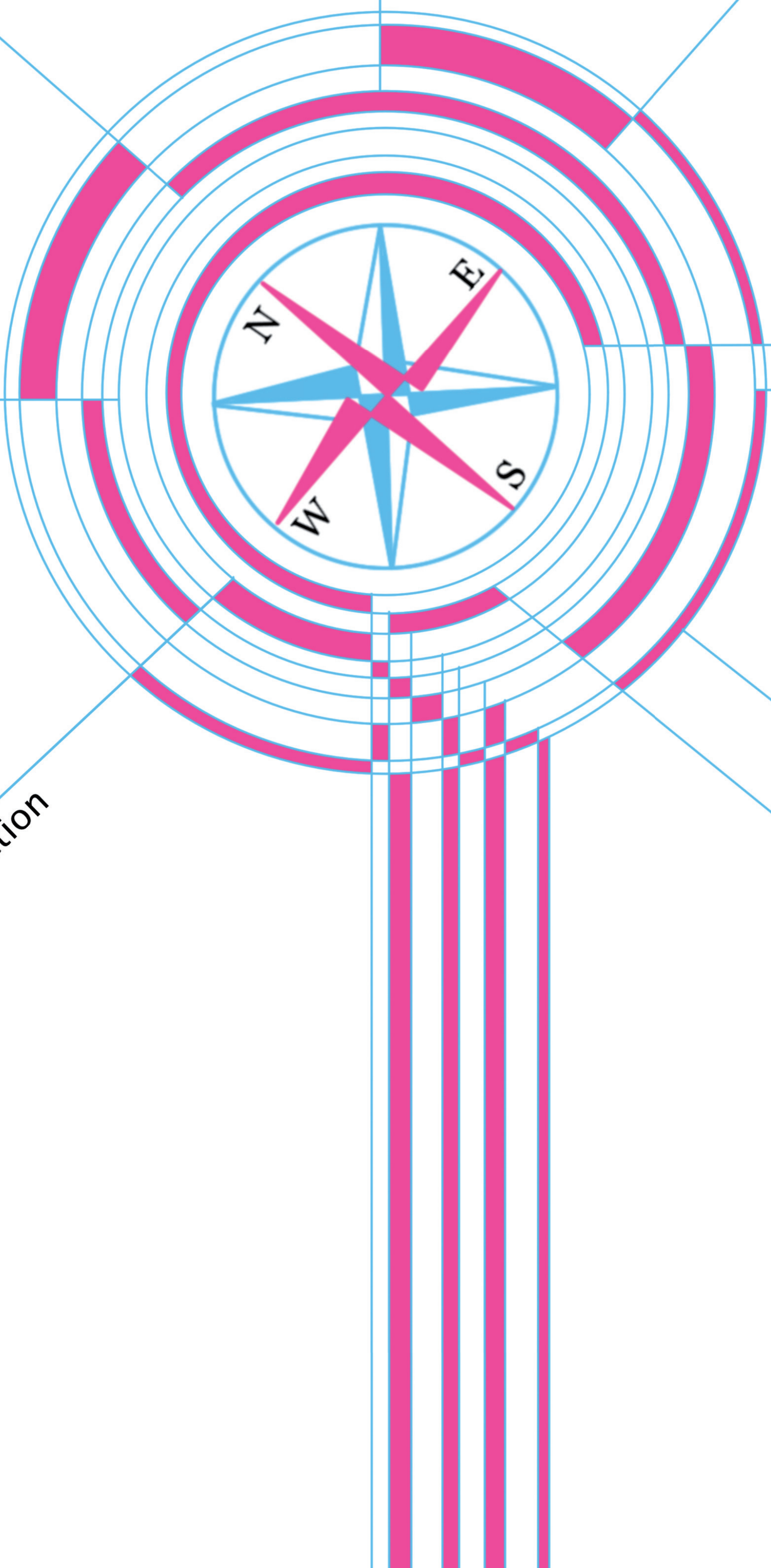
risk of missing one single talent. A coordinated approach is necessary, because implementing different talent programs in every single sports federation leads to fragmentation of the scarce resources.

First steps have been made by starting up the Flemish sports compass project. Cooperation is the key for small countries. Talent detection in primary schools is the first step to be taken. The advantages are various and children learn to make choices, which is beneficial for their autonomy and competence. Children have different reasons for practicing sports. Some are interested in competition some are not and a few believe in their chances to win medals for their country. Whatever the underlying motivation, we assume that children choose their appropriate sport, although it is obvious that also the sport chooses the child, because the sport demands specific characteristics. This doctoral dissertation intends to to formulate a scientifically based proposal for the implementation of the Flemish Sports Compass. Undermentioned you find the detailed report.

SAMENVATTING

De af te leggen weg van beginner tot kampioen is lang en onvoorspelbaar en daarom zal een sportkeuze die aansluit bij de individuele eigenschappen, waarschijnlijk leiden tot een langere sportparticipatie omwille van succeservaringen. Het Vlaams Sport Kompas is een generieke testbatterij die ontworpen werd om kinderen een gemotiveerde sportkeuze aan te bieden. Het instrument is uniek omdat het naast het meten van antropometrische en fysieke talentkenmerken ook aandacht heeft voor de motorische eigenschappen. Naast talent detecteren en talent oriënteren vormt deze generieke testbatterij de basis voor verschillende afgeleide testbatterijen om sportspecifiek talent te identificeren. Het Vlaams Sport Kompas bestaat uit eenvoudige tests die zowel bij kinderen in de lagere scholen als bij de leerlingen van de topsportscholen worden toegepast. Enerzijds kan er een onderscheid gemaakt worden tussen goede en minder goede bewegers en anderzijds stelt deze testbatterij ons in staat om sportspecifieke eigenschappen te onderzoeken. Het eerste deel van dit werk bestaat uit twee inleidende hoofdstukken. Het eerste hoofdstuk omvat definities, modellen en systemen van talent. Het tweede hoofdstuk behandelt de noodzaak en de voorbereidende studies om een sportkompas te ontwerpen. In het tweede deel van deze doctoraatsverhandeling worden zes originele studies gerapporteerd. De eerste studie belicht de potentiële toepassingsmogelijkheden van het Vlaams Sport Kompas voor de kinderen in het basisonderwijs. De verschillen tussen sportprofielen zijn minder uitgesproken dan in de tweede en de derde studie, waar leerlingen van de topsportscholen en de beloftevolle atleten uit de sportfederaties werden gemeten. De eerste drie studies geven aan dat de tests van het Vlaams Sport Kompas kunnen worden ingezet bij zowel beginnende sporters als bij elite atleten en ze geven tevens op elk niveau verschillen weer tussen de betere en de minder goede bewegers/sporters. De vierde studie gaat nog een stapje verder en geeft aan dat de generieke tests van het Vlaams Sport Kompas ook nog een onderscheid kunnen maken tussen de absolute top en de subtop in het volleybal. De talentkarakteristieken die gemeten worden met het Vlaams Sport Kompas zijn niet alleen goede voorspellers van atleten die de top kunnen halen, ze voorspellen ook wie kans maakt om de rol te moeten lossen. In de vijfde studie werd een survival-analyse toegepast. Zoals in de geneeskunde onderzocht wordt welke medicatie de patiënt betere levensverwachtingen kan bieden, zo werd in deze studie nagegaan hoeveel meer kans een atleet maakt om door te kunnen groeien tot elite atleet. De laatste studie geeft aan wat het belang is van predictieve analyses op een generieke testbatterij. Artificiële neurale netwerken kunnen de kosten van talentontwikkeling verminderen door efficiënter te selecteren. Tenslotte worden de verschillende studies besproken, bedenkingen weergegeven en aanbevelingen aangereikt in het derde deel van dit werk.

De studies in dit werk bieden kansen om een specifiek talentsysteem voor een klein land uit te bouwen. Vlaanderen heeft het nadeel dat het moeilijk kan concurreren met reuzen zoals China, Rusland en de Verenigde Staten. Het nadeel van kleine naties is dat die een minder uitgebreide talentpool hebben, hetgeen weer een voordeel kan zijn doordat ze precies klein genoeg zijn om geen enkel talent te missen. Daarom is een gecoördineerde aanpak noodzakelijk; het ontwikkelen van talentprojecten binnen elke federatie versnippert de schaarse middelen. Talent detecteren in de basisscholen is de eerste stap die genomen moet worden. De voordelen zijn divers want de kinderen leren keuzes maken, wat hun autonomie en competenties ten goede komt. Kinderen gaan om verschillende redenen sport beoefenen. Sommigen zijn geïnteresseerd in het wedstrijdelement, anderen kiezen voor een sport omwille van het plezier en de vrienden en slechts enkelen willen (en kunnen) medailles winnen voor hun land. Welke ook de onderliggende motivaties mogen zijn, we gaan ervan uit dat ze meestal hun eigen pad kiezen, hoewel het opvallend is dat de sport ook het kind kiest. Elke sport vraagt immers specifieke karakteristieken. Het ligt de bedoeling om via deze doctoraatsthesis een wetenschappelijk gefundeerd voorstel voor de implementatie van het Vlaams Sport Kompas te formuleren. Hieronder wordt dit gedetailleerd uitgewerkt.



Part 1: Introduction

1.1 INTRODUCTION

Talent detection, identification and development of youth in sport, in the quest for international or professional athletic success are issues that face major sporting bodies. The non-uniform use and lack of universal agreement on the nomenclature selected to describe sport talent, its' potential and success further complicate an already complex issue (Suppiah et al., 2015). First, it is important to define frequently used terms in talent research.

1.1.1 DEFINITIONS

There is no single definition for ***"Talent".*** Indeed, talent can be considered as the basis for the prediction of domain-specific performance, which indicates that someone is ahead of his or her peers. Talent is in part genetically determined and occurs only for a limited number of individuals in a population. It appears that this explicit definition of Howe and colleagues (1998) has been accepted by many researchers studying how to develop talent in young children. Howe et al. (1998) assigned five properties to talent (a) it originates in genetically-transmitted structures; (b) its full effects might not be evident at an early stage, but there will be some advance indications, allowing trained individuals to identify the presence of talent before exceptional levels of mature performance have been demonstrated; (c) these early indications of talent provide a basis for predicting who is likely to excel; (d) only a minority is talented; and (e) talents are relatively domain-specific. In the Differentiated Model of Giftedness and Talent (Gagné, 2004) a distinction was made between two concepts. ***"Giftedness"*** designates the possession and use of untrained and spontaneously expressed natural abilities (called outstanding aptitudes or gifts), in at least one ability domain, to a degree that places an individual at least among the top 10 per cent of age peers. ***"Talent"*** designates the outstanding mastery of systematically developed abilities (or skills) and knowledge in at least one field of human activity to a degree that places an individual at least among the top 10% of age peers who are or have been active in that field or fields. Unfortunately no further scientific arguments were found to support this arbitrarily chosen 10% limit. Tannenbaum (1993) applied even a stricter margin and defined talent as the ability to perform common skills in each stage of development to less than 2% of the population.

Besides the basic definition of talent there are some key terms that can be clearly defined before going into an in depth overview of present research.

"Talent Characteristics" are features indicating that athletes can rely on natural abilities so that they will belong to the best of their age group within a particular discipline (Müller et al., 2000). The knowledge of the required specific characteristics is essential to validate generic and sport specific test batteries. In talent identification field tests are often used to assess a certain characteristic. The usefulness of these tests causes them for different sports (e.g. generic tests).

"Talent Detection" refers to the discovery of potential performers in a heterogeneous population of young people who are currently not involved in a specific sport (Vaeyens, 2007).

"Talent Identification" alludes to the process of recognizing current participants with the potential to excel in a particular sport (Williams & Reilly, 2000).

"Talent Development" is offering optimal development and training opportunities by providing the most appropriate learning environment to achieve the maximum level of performance in a particular sport (Vaeyens et al., 2008).

"Talent Selection" involves the ongoing process of identifying players at various stages that demonstrate qualification levels of performance for inclusion in a particular team (Vaeyens, 2007). It is perceived as "very short-term talent detection" as it is related to determining the most suitable athletes for a particular task at a given time (Williams and Reilly, 2000).

"Talent Transfer" is the opportunity that is offered to high- performance athletes to transfer their athletic ability to another sport. This shift in talent identification and development systems to increase the probability of identifying athletes that can attain senior expertise by minimizing adolescent maturational issues, reducing talent development time frames, and maximizing return on the developmental investment already made in these older athletes (Gulbin & Ackland, 2009; Halson, et al., 2006; Bullock et al. 2009).

"Talent Confirmation" is the validation of the decision that was made at the talent identification process. After the baseline decision that was made to develop the talent of an athlete, an additional evaluation confirms the identified talent (Vayens 2007).

In the scope of this dissertation three definitions are introduced. First ***"Talent Orientation"*** is related to talent detection and aims at motivating youngsters to choose a sport that matches the individual talent characteristics to one or more specific sport(s). For some sports an early talent orientation is necessary because of the very young age of athletes at the highest level (Papic, 2009). Second the difference between a ***"Talent Model"*** and a ***"Talent System"*** will be explained by the theoretical design for the talent model and the practical application of a nationwide-implemented talent system.

1.1.2 TALENT MODELS

During the last decades different models were presented to frame the search for talent. We summarized the discussed talent models (in addendum) into five research clusters. The clusters successively discuss the role of performance prediction; giftedness and talent; nature and nurture; deliberate practice ande deliberate play and the applied talent research methods in the different models.

PERFORMANCE PREDICTION

A first cluster highlights the 'performance prediction'. The multifactorial approach in order to detect and identify talent, combined with a longitudinal follow-up and multiple regression techniques was introduced in the seventies by different sports scientists who investigated the relation between predictors and performance. (Wolkow, 1974; Bar-Or, 1975; Jones & Watson, 1977; and Geron, 1978). Even though our study is specifically focussed on anthropometric, physical and motor performance characteristics, the psychological skills are discriminators between the elite and sub elite performers according to Abbott and Collins (2004) the latter based their model on the research of Bar-Or (1975) who conceived a five step approach to talent detection, involving; (a) the evaluation of morphological, physiological, psychological and performance variables; (b) the comparison of data with a developmental index to account for biological age; (c) response to training; (d) family history; and (e) the use of a multiple regression analysis. Gabler & Ruoff (1979) were the predecessors of an important milestone in talent research i.e. the sliding population approach (Règnier et al., 1993). The sliding population approach is based on different test batteries to assess performance predictors for different age groups (Figure 1). Later, Balyi & Hamilton (2004) converted the sliding population approach to the Long Term Athlete Development model (LTAD), which is a practical model implementing the scientifically contested windows of opportunity (Ford et al., 2011; Tucker 2014).

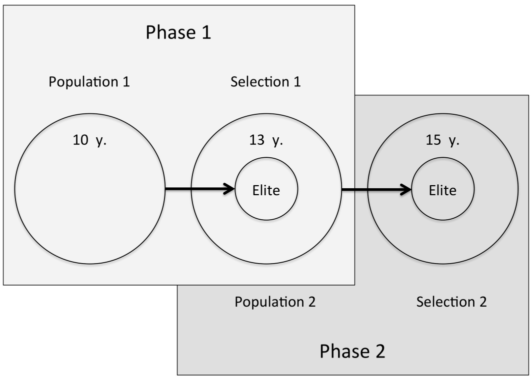


Figure 1: The sliding population approach (adapted by Régnier et al., 1993)

GIFTEDNESS AND TALENT

The second cluster describes the evolution from giftedness to talent. Geron (1978) already highlighted the distinction between the raw materials and systematically developed skills, which was adapted by Gagné's differentiated model of giftedness and talent (2004) describing how gifts can be developed into talent. Bloom (1985) and Csikszentmihalyi et al. (1993) presupposed that talents could not develop without nurturing through a developmental process and favourable environmental factors. Csikszentmihalyi et al.'s study was similar to Bloom's because both researchers selected talented individuals across the domains of arts, sport, music, mathematics and science. An important difference was how both studies used the word talent. While Bloom used the term 'talent' to describe an unusually high level of demonstrated skill, Csikszentmihalyi et al. used 'talent' in reference to gifts and aptitudes as well as competencies and talents. Csikszentmihalyi et al.' s participants were nominated as gifted by teachers. In contrast Bloom's participants were selected for their outstanding achievements (talent). Bloom's participants developed their gifts to a talented level, while Csikszentmihalyi et al.'s (1993) participants were all identified as gifted but had not yet reached the level of being talented.

Gagné (2004) made a clear distinction between giftedness and talent. The "Differentiated Model of Giftedness and Talent" (DMGT) describes how natural abilities can become systematically developed skills influenced by several factors. Talent can thus be developed by transforming gifts 'raw material' into talent 'ultimate achievement' through a process of learning, practice and training influenced by various intrapersonal and environmental factors 'catalysts' and chance. Intrapersonal catalysts include physical characteristics, motivation, volition, self-management and personality. Environmental catalysts include friends and peers, social class, economical and geographical factors and the way in which the environment is structured to facilitate training improvement (Figure 2).

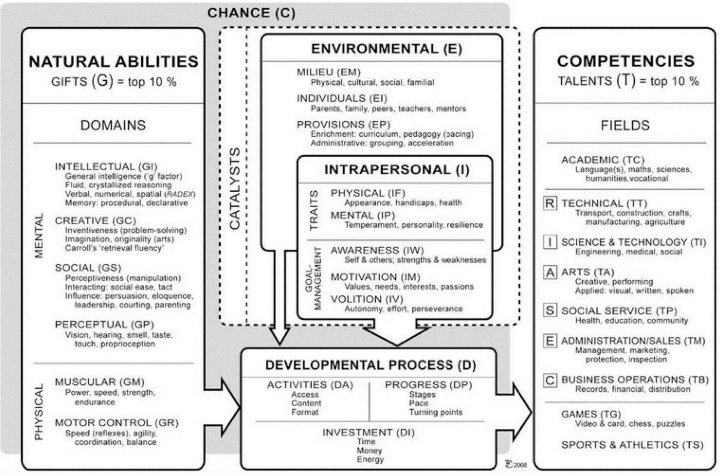


Figure 2: The Differentiated Model of Giftedness and Talent (Gagné, 2004)

Parallel to the DMGT developed by Gagné a similar model was developed by Heller (2004) The "Münchner Hochbegabungsmodells". This model was based on talent characteristics (predictors) environmental factors and personality traits (moderators), which result in performance areas. The model is based on four interdependent multifactorial dimensions: talent factors (relatively independent), resulting performance areas, personality factors, and environmental factors, the latter two moderating the transition from talent (gifts) to performance. Gulbin et al. (2010) evaluated the theoretical model of Gagné and surveyed a large pool of high performance athletes (n=673 including 51 Olympians) to look back at their experiences of their athletic development and to provide additional insights to refine talent development pathways for the next generation of athletes. The Athlete Development Triangle is characterised by an inherent flexibility within its design to account for progression, digression and direct crossover (i.e., junior to senior) in competition levels. It made it possible to establish a more meaningful and realistic map of the journey to an elite status than has been provided in the literature to date (Figure 3).

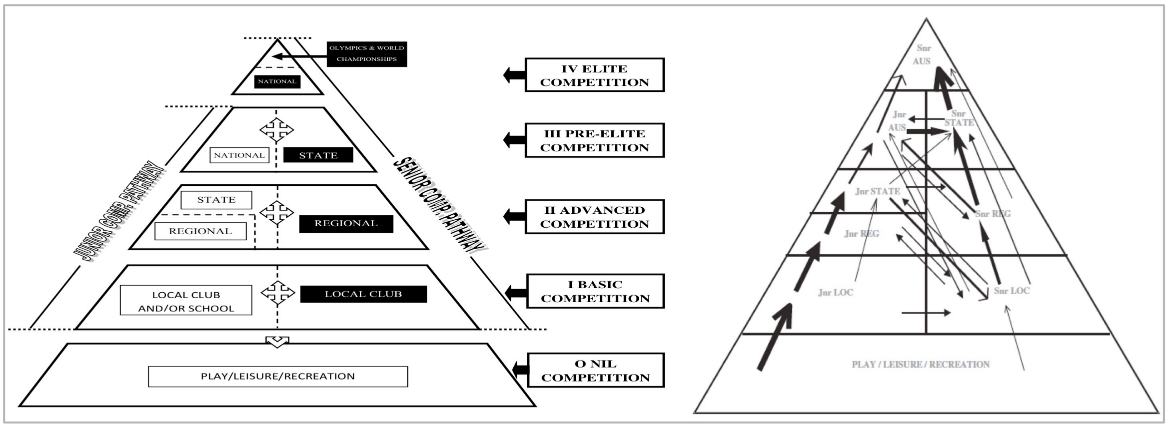


Figure 3: Transitions in the Athlete Development Triangle (Gulbin et al., 2010)

NATURE – NURTURE

A third cluster deals with the often-discussed nature-nurture debate. Howe et al. (1998) rely on the position that if innate giftedness exists than this talent would be detectable at an early age. Their tenant is that if early, predictive detection of talent is lacking, then talent must not exist, and therefore, only training, motivation and self-confidence can explain expert performance. Others disagree. Rose (1995) stated that people inherit dispositions, not destinies. However it appears that until a direct connection can be verified between genetic predispositions and sport performance, the debate will continue Johnson & Tenenbaum (2006). Nature refers to the innate ability to excel within a sport while nurture means developing skills through an extended amount of high quality training (Davids et al., 2007). It is not presently possible to ascertain the exact relative contribution of either genes or training to elite sporting performance, and it must be recognised that it is likely that the relative importance of training may differ for different sports, such that in some sports, genetic factors may be more significant (Tucker and Collins, 2012).

The literature on genetics supports both concepts of innate giftedness and environmental influence on expertise in sport. Research in the areas of twins and adoption, behavioural, cognitive, physical, physiological, maturational, and gene-environment interactions and correlations relate to the development of expertise in sport (Johnson & Tenenbaum, 2006). 214 gene entries have been included in the human gene map for performance (Bray et al, 2009). In a review on the current state of affairs in sports genetics and its role in the future, Pitsiladis et al. (2013) highlight the ACE and ACTN3 genes as potential candidates that are associated with human physical performance. However, the authors categorically clarify the infancy of the field in determining elite success based on gene analysis and further, state its absence of predictive power in talent identification. This lack of predictability was evident in a case study involving an elite Spanish Olympic long jumper, with a history of international accolades in this event, who was ACTN3 deficient, Lucia et al (2007), which is widely reported (Pitsiladis et al., 2013) to be unfavourable for speed and power events, and more suited for endurance performance. (Suppiah et al, 2015)

The early estimates of heredity claimed up to 90% of the aerobic endurance (VO2max) to be innate (Klissouras, 1971). Today, only 50% of the aerobic endurance is attributed to genes (Hopkins, 2001). Since heredity of certain characteristics turned out not to be as important as previously thought, science examined the stability of performances over the course of the motor development and the training history of young athletes. Bouchard et al (1997) are leaning toward the direction that not only different abilities and traits but more important the trainability of the athlete itself is the most important innate factor. These authors distinguish between high and low responders according to their inherited responsiveness to training.

DELIBERATE PRACTICE – DELIBERATE PLAY

The fifth cluster covers the contrast between deliberate practice and deliberate play. The shift from deliberate practice expressed by Harre (1982) e.g. ‘talent is trainable’ and Ericsson et al., (1993) ’10.000 h.’ to the idea of deliberate play from Coté (2007) and further to deliberate programming of Bullock (2009) overwhelm the idea of a deliberate choice. Playing, training and programming are indispensible in the development from giftedness to talent. Attaining sport expertise does not happen in the absence of practice and play, in a deliberate form or otherwise. A diverse exposure to sport, and the intricate details of the developmental route undertaken by a successful elite athlete largely depends on the nature of the sport, and the culture and context of the country. Caution is warranted in adopting a dichotomous or a ‘one-model-fits-all’ approach to developing sport expertise in youth and beyond (Suppiah et al., 2015). A wrong choice is detrimental for fun experience and will never compensate training. In the long run it is important to provide a deliberate choice by orienting children towards sports that fit their capacities and interests. This position statement does not have to be contradictory with encouraging wholesome sport experiences in competition settings without too much structured training and sampling as many physical activities and sports in the context of play (Suppiah et al., 2015).

TALENT RESEARCH METHODS

The fourth cluster covers the applied methods. The choice between prospective and retrospective research justify the applied statistical methods. Looking back at athletic development provides insights to refine talent development pathways as was shown by Gulbin (2010). Bloom (1985) already applied retrospective interviews to provide important information for the next generation. The retrospective approach is in contrast with the performance prediction using different statistical methods with the evolution from linear to non-linear profiling and modelling techniques. The application of basic statistical methods starts with profiling of elite athletes based on raw scores (Gimbel 1976; Geron 1978), followed by profiling based on normalized scores i.e. z-scores (Matsudo 1986); or MQ-scores (Kiphard and Schilling 2007) in the quest of discovering extremely deviating performances. Abbott and Collins (2002) suggested that talent identification systems exclude many gifted children and at the same time select individuals who will eventually fail to develop their talents. The influence of the maturity status and the influence of previous experience are factors that deserve more attention in this context. The possibility to compensate talent characteristics supported their objection against the effectiveness of one-dimensional models, with a higher risk to select false positives and to de-select false negatives (Figure 4).

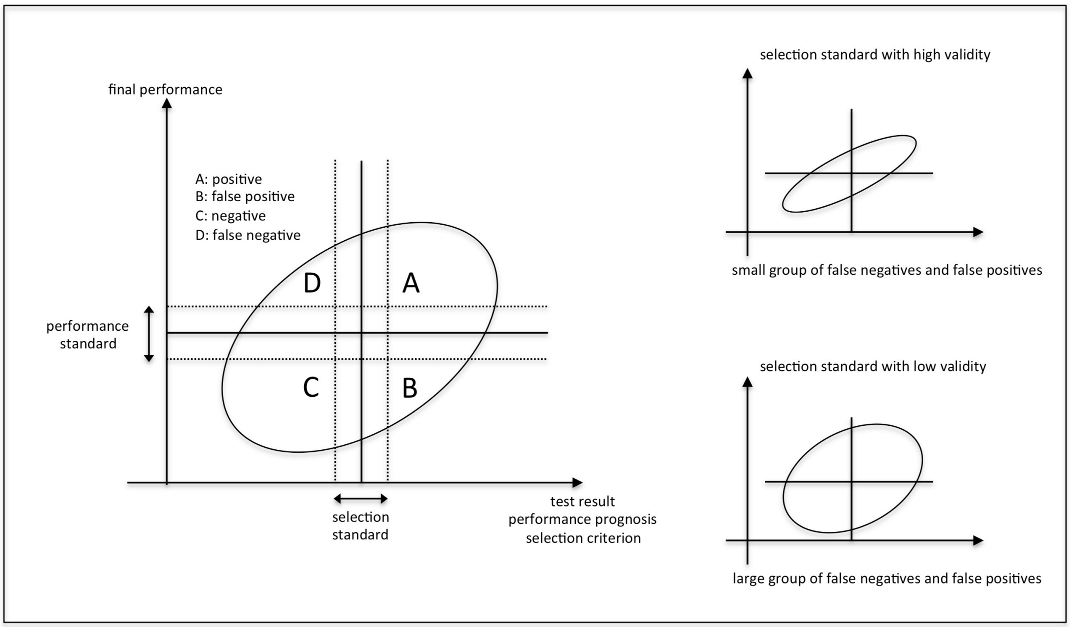


Figure 4: Risk of error in talent selection due to the uncertainty of performance prognosis (According to Baur 1988)

The statistical models are intended to reduce errors in talent selection. The early talent models already applied linear regression techniques to predict elite performance, Wolkow (1974) and during the last few decades discriminant analysis and artificial neural networks were applied for talent identification (Hohmann, 2009, Allen et al., 2014).

1.1.3 TALENT SYSTEMS

The discussed scientific talent models (in addendum) are the basis for nationwide-implemented talent systems. The successful talent identification system of the former German Democratic Republic (GDR) is the predecessor of different successful talent systems developed during the next decades i.e. the Australian Institute of Sport (AIS), UK Sports Performance Pathway Team, and the Talent identification Unit at Japan Sport Council. There has been a lot of criticism of the talent detection, talent identification and talent development system from the former Eastern Bloc. Especially the GDR State Plan 14:25 (Hungermann, 2006) is the cause of a negative connotation of talent identification, partly because systematic doping was given to the athletes. Some components of the former GDR sport exhibited large costs, but not equivalent outcomes. The GDR performance system incorporated systematically all young children, while the western policy was to identify and support talented individuals after they became successful. The compulsory talent detection in the German primary schools caused an extraordinary influx of talented athletes in different sports and the selection of the better and the ruthless elimination of the weak were implemented during the different development phases. The primary schools were obliged to refer the 70,000 gifted athletes to one of the 2000 youth sports schools. The further development in 25 “Child and Youth Sport Schools” with 13,000 students and clubs was sport specific, with significant financial and material support for more than 6,000 trainers (compared to 120 in West Germany) (Güllich & Emrich, 2013). Talent development necessitated full-time commitment of the athlete/coach. Furthermore the quest for specific sports disciplines with the opportunity to score at international competitions was opened. The Eastern athletes specialised earlier in one sport, participated less in other sports. These athletes performed much more specialised training during youth and adulthood, and used athlete services more intensively. They attained greater early success during youth, but not greater senior success. The economic inefficiency at the collective level of many sport organisations is apparently mirrored in lower efficiency of investment at the individual level of Eastern athletic careers (Güllich & Emrich 2013). Nevertheless the search for sports talent became an important issue for numerous countries in their struggle for Olympic medals.

The nineties were characterised by the rise of the Australian sports system. In 1989 the Australian Sports Commission decided that it would target sports in which Australia could do well internationally and seven sports were chosen. The budget for the program was $ 10 million, to be divided between basketball, canoeing, cycling, hockey, rowing, swimming and track and field. Additional funding made it possible to appoint an international-level elite head coach for each sport, to establish a state-based Intensive Training Centre (ITC) and to make international competition more available for athletes in the above sports. By the early 1990s, targeted support was beginning to work well when the Olympic Athlete Program commenced. The Australian Institute (AIS) developed the first successful talent detection programme in the western world called the 'Talent

Search'. This programme was inspired by Dr. Hahn's successful detection of talent in rowing and led to the Australian rowers being fast tracked to the 1992 and 1996 Olympics (Tranckle, 2005). The combination of the establishment of more state or territory institutes/academies of sport, the increasing development and decentralisation of the AIS and the cooperation of the national sports organisations has contributed to an effective and efficient national elite sports program in Australia. The medal tally from the targeted sports increased from 12 in Seoul in 1988 to 22 in Barcelona in 1992 to 31 in Atlanta in 1996, reaching a total of 37 in Sydney in 2000 (Bloomfield, 2003). During the talent identification conference in Qatar (2014), two sport scientists noticed that the Australian system has known better days with more funds. AIS impose targets and supports different projects in different regions. The regions now adopt the National TID model of the 2000s'. Sport is considered as a product with managers who impose objectives to the performers. Tight deadlines and high standards are the norm. First the project ‘Prospecting for gold’ in Queensland targets two or three participants for the Olympic Games in Rio 2016, the quest for talent includes identifying and a fast development course to become a World Class Athlete in 20 months. (Mewing, 2014). Secondly, the limited funds and some Non-Olympic sports being more important are difficulties to be overcome, especially in a vast area with a relatively small population. The ‘SASI talent search’ (Eastwood, 2014) challenges the demographic problems. The system consists of three phases. The first phase is the talent detection in schools. The second phase is the advanced testing combined with sport specific tests. The third phase is the talent development phase. The campaign ‘Backwards to London’ supports the 'Talent Developing Pathways' supported by the talent identification systems of different sports federations to optimise talent inflow.

Two projects with excessive budgets characterized the start of the new millennium. First, in China ‘Project 119’ was launched in 2002, the name of the program alluded to the number of medals that China wanted to achieve during the Olympic Games in their own country in 2008 (Jones, 2008), the government supported athletes in sports that traditionally yielded less medals in previous Olympics, with unlimited funds to achieve success in athletics, canoeing, rowing, sailing and swimming. Second, at the same time the UK Sport programs were launched in Britain in 2002 in preparation of the London Olympics in 2012. UK Sport is currently the shining example and has a lot of resources in comparison with other countries. Having a clear vision and starting with the end in mind are important recommendations handed by Stuart Laing at the talent identification conference in Qatar (2014). Both advices need sustainable high performance systems, where each layer operates in function of the following layer to find the right athlete in the right environment (Laing 2014). UK Sport generates most of the funds and is considered a bank that stands between the government and the sports federations. The key tasks are to improve the climate of the sport by performance monitoring and evaluation of sport systems and structures. Talent identification is one of the five departments where talent identification; talent selection; talent transfer; talent confirmation and World-class development succeed each other. Since 2007, major campaigns were launched to find athletes: Sporting Giants males (2007);

Sporting Giants females (2008); Paralympics (2009). The success of this well organised system was shown in the medal standings at the London Olympics in 2012. For Rio 2016, 60% of the funds are used; the remaining 40% will be spent on projects for Tokyo 2020. Compete to stage (2011); Fighting Taekwondo Champ (2012); Campaigns through YouTube and Twitter (2014) were the latest campaigns to promote elite sports.

It is clear that the examples of the China and Great Britain are not possible for small countries, because of the excessive budgets for talent programs and the large size of the population from which these countries could recruit. The Netherlands and Canada implemented the Long Term Athlete Development (LTAD) model (Balyi, 2001 and 2007). The concept focuses on the general development of the athlete. However, different sport scientists discuss this model since there is a lack of scientific evidence for the “Windows of opportunity” (Ford et al., 2011; Tucker 2014). Inspired by the Australian Sport search programme “eTID” a similar interactive pilot programme “Sport Interactive” was used by Sportscotland. This interactive computer package matches young people to sports based on sporting preferences and on performance of a number of simple physical activity tasks (Wolstencroft 2002).

Many countries started to copy the successful talent transfer strategy to improve their chances in addition to a development strategy over a shorter time to get the best possible return. The nationwide-implemented talent system mostly targets the next Olympic games and in many cases another four years later. Douglas (2014) presented a talent system for Qatar, with the ambition to screen every boy in Qatar to lead high potentials to Aspire Academy. The system contains the same three phases of the former Australian campaign (bronze, silver and gold). The “Bronze” phase is a large-scale screening in 47 schools (3000 boys of 11 years). In this detection phase the aim is to select high potentials while avoiding to not de-select children. The test battery includes generic measurements i.e. stature, weight, BMI, armspan, APHV, sprint 40m, endurance shuttle run, vertical jump, medecinbal throw (2kg). During the “Silver” phase 150 to 200 boys are invited to perform the same tests with the intention to validate the results of the first phase. In addition, coaches from different sports observe the selected boys. This is the final assessment or “Gold” phase for 60 to 80 boys who are invited to participate at the ultimate boot camp. Sport specific assessments and motor coordination will lead to 30 newcomers in Aspire Academy. To become successful, the aim is to consider all PE teachers as partners in this project. The evaluation of the boys in their own schools will lead to the detection of more high potentials.

Finally the Japanese model (Kinugasa, 2014) offers new dimensions to existing systems. The target is Tokyo 2020 and therefore short-term actions are combined with long-term projects. The system includes talent detection; talent identification and talent transfer resulting in 700 selected athletes for 12 regional centres. Three different types of talent academies were introduced first the classic talent academy with preliminary screenings and selections in a particular sport. Secondly specific Talent Transfer Centres try to transform outstanding athletes into new sports that suit their abilities. Third, the new Multi-Sport Centres develop high potentials (12-14 y) by means of sports clusters. This high level generic development based on clustered talent characteristics leads towards a future sports specialisation.

Today, most countries are trying to develop structures to identify exceptionally gifted athletes at an early age aiming to focus available resources on particularly promising individuals and promote their development in a certain sport (Abernethy, 2007). The search for talent has led to, among other initiatives, the foundation of specialized organizations like the Child and Youth Sport Schools in Eastern European countries, and other national talent search programs such as the Australian Institute of Sport, ASPIRE in Qatar, and the UK High Performance Talent Program. Such institutions may be significant for tapping a larger proportion of potential talent. Talent search can be considered valuable in particular for sporting organisations in countries with a relatively small population that when compared with "giants" like China, the USA or Russia, can understandably only rely on a small pool of gifted individuals (Vaeyens et al., 2009).

Sport is one of the government authorities of Flandres (the dutch speaking part of Belgium, with a total of 7,6 million inhabitants). The best practices of the different systems are essential for the talent search in small countries and simply adopting a talent system exclusively designed for the specific needs of another nation is not possible. For smaller countries the balance between efficiency and effectiveness is extremely important. Efficiency expresses the ratio between input and output. To improve the efficiency of the talent search, a greater output with equal input or an equal output with reduced input of resource investment is necessary. The effectiveness of the talent search is expressed by the degree of achievement of the set objectives. Therefore, the assumption that a talent detection phase can improve talent search is based on the perception that Talent identification test batteries operate in only one sport while a Talent detection test battery is advantageous for different sports simultaneously. Implementing generic tests in different sports is the starting point for a new approach and meets all aspects of talent research, i.e. talent detection, talent identification, talent selection, talent orientation, talent transfer, talent confirmation.

References

1. Abbott A, Collins D (2002). A theoretical and empirical analysis of a ‘state of the art’ talent identification model. *High Ability Studies 2002*; 13 (2): 157‐78.
2. Abbott A, Collins D (2004). Eliminating the dichotomy between theory and practice in talent identification and development: Considering the role of psychology. Journal of Sports Sciences, 22, 395–408.
3. Abernethy, A. B. (2007). Developing expertise in sport: How research can inform practice. Developing elite sports performers: Lessons from theory and practice, 1-14.
4. Allen, S. V., Vandenbogaerde, T. J., & Hopkins, W. G. (2014). Career performance trajectories of Olympic swimmers: Benchmarks for talent development. European journal of sport science, 14(7), 643-651.
5. Balyi I (2001). Sport System Building and Long‐term Athlete Development in British Columbia. Sports Med BC, Canada.
6. Balyi I, Hamilton A (2004). Long-term athlete development: Trainability in childhood and adolescence. Olympic Coach, 16(1), 4-9.
7. Balyi I (2007). *Introduction to Long Term Athlete Development, in Talent centraal, NOC‐NSF*, Editor. 2007, NOC‐NSF: Papendal (NL).
8. Bar‐Or O (1975). Predicting athletic performance, *Physician and sports medicine* 3 (2): 81‐85.
9. Bloom BS (1985). *Developing talent in young people*. New York: Ballantine, 1985.
10. Bloomfield J (2003). *Australia's sporting success: The inside story*. UNSW Press.
11. Bouchard, C., Malina, R. M., & Pérusse, L. (1997). *Genetics of fitness and physical performance*. Human Kinetics.
12. Bray, M., Hagberg, J., Perusse, L., Rankinen, T., Roth, S., Wolfarth, B., & Bouchard, C. (2009). The human gene map for performance and health-related fitness phenotypes: the 2006-2007 update. *Medicine+ Science in Sports+ Exercise*, *41*(1), 35.
13. Bullock N, Gulbin JP, Martin DT, Ross A, Holland T & Marino F (2009). Talent identification and deliberate programming in skeleton: Ice novice to Winter Olympian in 14 months. *Journal of sports sciences*, *27*(4), 397-404.
14. Côté J, & Fraser-Thomas J (2007). *The health and developmental benefits of youth sport participation*. Toronto: Pearson.
15. Csikszentmihalyi M, Rathunde K, Whalen S (1993). *Talented teenagers: The roots of success and failure*. New York: Cambridge University Press.
16. Davids, K., & Baker, J. (2007). Genes, environment and sport performance. *Sports medicine*, *37*(11), 961-980.
17. Douglas A (2014). *Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014 “Sifting the sands – Talent identification at Aspire Academy*. Qatar.”
18. Eastwood A (2014). Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014 “Talent Identification in South Australia. Challenges, interventions and successes”
19. Ericsson KA, Krampe RT & Teschromer C. (1993). The role of deliberate practice in the aquisition of expert performance. *Psychological Review, 100*(3), 363-406.
20. Ford P, De Ste Croix M, Lloyd R, Meyers R, Moosavi M, Olive J, Tiill K & Williams C (2011). The Long‐Term Athlete Development model: Physiological evidence and application, *Journal of Sports Sciences*, 29:4, 389‐402.
21. Gabler H, Ruoff BA (1979). Zum problem der Talentbestimmung im Sport, *Sportwissenschaft* 9 (2) : 164‐180.
22. Gagné F (2004). Transforming gifts into talents: the DMGT as a developmental theory. *High Ability Studies*, 15(2): p. 119‐147
23. Geron E (1978). Psychological assessment of sport giftedness, in Simri U (ed.), *Proceedings of the international symposium on psychological assessment in sport*, Nataya : Wingate Institute, 216‐231.
24. Gimbel B (1976). Possibilities and problems in sport talent detection and research [in German]. *Leistungssport* , 6: 159‐67.
25. Güllich A & Emrich E (2013). Investment patterns in the careers of elite athletes in East and West Germany. *European Journal for Sport and Society*, *10*(3), 191-214.
26. Gulbin JP & Ackland TR (2009). Talent identification and profiling. *Applied Anatomy and Biomechanics in Sport, Champaign IL, Human Kinetics*, 11-26.
27. Gulbin J, Oldenziel K, Weissensteiner J & Gagné F (2010). *A look through the rear view mirror: Developmental experiences and insights of high performance athletes*.
28. Güllich A & Emrich E (2013). Investment patterns in the careers of elite athletes in East and West Germany. *European Journal for Sport and Society*, *10*(3), 191-214.

29. Halson S, Martin DT, Gardner AS, Fallon K & Gulbin J (2006). Persistent fatigue in a female sprint cyclist after a talent-transfer initiative. *International journal of sports physiology and performance*, *1*(1), 65.
30. Harre D (1982). *Trainingslehre*. Berlin: Sportverlag.
31. Heller K (2004). Identification of Gifted and Talented Students, *Psychology science*, Volume 46, (3), p 302-323.
32. Hohmann A (2009*). Entwicklung Sportlicher Talente an Sportbetonten Schulen, Shwimmen-Leichtathletik-Handball*, Michael Imhof Verlag Gmbh&Co.KG, Petersberg.
33. Hopkins, W. G., & Hewson, D. J. (2001). Variability of competitive performance of distance runners. *Medicine and Science in Sports and Exercise*, *33*(9), 1588-1592.
34. Howe MJA, Davidson JW and Sloboda JA (1998). Innate talents: Reality or myth? *Behavioral and Brain Sciences*, 21(3): p. 399 - 442.
35. Hungermann J. Viele ehemalige DDR-Leistungssportler können kaum noch stehen. (2006). [Cited 2006 22 november] Available from: http://www.welt.de/sport/article96480.
36. Johnson, M. B., Tenenbaum, G., & Edmonds, W. A. (2006). Adaptation to physically and emotionally demanding conditions: The role of deliberate practice. *High Ability Studies*, *17*(1), 117-136.
37. Jones G (2008). China's olympic plan to topple America [cited 2008 1 august] Available from: http://www.thefirstpost.co.uk/45023,news-politics, chinas-119 olympic-dreams.
38. Jones JG, Watson GG (1977). Psychological factors in the prediction of athletic performance, in Simri U (ed.), *Proceedings of the international symposium on psychological assessment in sport*, Nataya: Wingate Institute, 89-102.
39. Kinugasa T (2014). Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. “Targeting Tokyo 2020 and beyond/ The Japanese TID model”.
40. Kiphard EJ, Schilling F. (1974) Körperkoordinationstest für Kinder, Weinheim: Beltz Test Gmbh.Klissouras, V. (1971). Heritability of adaptive variation. *Journal of Applied Physiology*, *31*(3), 338-344.
41. Klissouras, V (1971). Heritability of adaptive variation. *Journal of Applied Physiology*, *31*(3), 338-344.
42. Laing S (2014). Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. 3 To the London Olympics and beyond – talent identification practices in the UK”
43. Lucia A, Olivan J, Gomez-Gallego F, *et al*. Citius and longius (faster and longer) with no alpha-actinin-3 in skeletal muscles? *Br J Sports Med* 2007;**41**:616–17. doi:10.1136/bjsm.2006.034199
44. Matsudo VKR, Rivet RE, Pereira MHN (1987). Standard score assessment on physique and performance of Brazilian athletes in a six tiered competitive sports model, *Journal of Sports Sciences*, 5, pp 49-53.
45. Mewing M (2014). Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. “*Prospecting for Gold – a novel talent identification and development approach at the Queensland Academy for Sport*”
46. Müller E, Benko U, Raschner C, Schwameder H (2000). Specific fitness training and testing in competitive sports. *Medicine & Science in Sports & Exercise*, Vol 32, N°1, pp 216-220.
47. Papic V, Rogulj N, Plestina V (2009), Identification of sport talents using a web-oriented expert system with a fuzzy module. *Expert Systems with application*, Vol. 36, pg. 8830-8838.
48. Pitsiladis Y, Wang G, Wolfarth B, *et al*. Genomics of elite sporting performance: what little we know and necessary advances. *Br J Sports Med* 2013;**47**:550–5. doi:10.1136/bjsports-2013-092400
49. Régnier G, Salmela J and Russell SJ (1993). Talent detection and development in sport. In Singer, R.N.; Milledge, M. en Tennant, L.K. *Handbook of research on sport psychology*, 290-313. New York: Macmillan Publishing company.
50. Rose, R. J. (1995). Genes and human behavior. *Annual review of psychology*, *46*(1), 625-654.
51. Suppiah, H. T., Low, C. Y., & Chia, M. (2015). Detecting and developing youth athlete potential: different strokes for different folks are warranted. *British journal of sports medicine*, bjsports-2015.
52. Tannenbaum A (1993). History of giftedness and "gifted education" in world perspective. In *International Handbook of Research and Development of Giftedness and Talent*, K.A. Heller, F.J. Mönks and A.H. Passow, Editors, Pergamon Press. p. 3-27.
53. Tranckle (2005). *Exploring how gifts are discovered and why talents develop in sport.* Brunel University, Department of Sports Sciences.
54. Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine*, bjsports-2011.

55. Tucker R (2014) Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. “The talent equilibrium: Finding balance between scientific prudence and strategic prerogatives”
56. Vaeyens R (2007). *Talent identification and selection in youth soccer, contribution from the perceptual-cognitivedomain in a multidisciplinary model*, doctoral dissertation, Gent University, Faculty of Medicine and Health Sciences, Department of Movement and Sports Sciences, ISBN 9789078836056.
57. Vaeyens R, Lenoir M, Williams AM, Philippaerts R (2008). Talent identification and development programmes in sport ‐ Current models and future directions. *Sports Medicine*, 38(9): p. 703‐714.
58. Vaeyens R, Gullich A, Warr CR, Philippaerts R (2009). Talent identification and promotion programmes of Olympic athletes. *Journal of Sports Sciences*, 27(13): p. 1367‐1380.
59. Williams AM & Reilly T (2000). Talent Identification and development in soccer. *Journal of Sports Sciences*, 18 (9): p. 657-667.
60. Wolkow WM (1974). Aktuelle Biologische Frage der sportlichen Auslese, *Leistungssport* 4 (6): 469‐472.
61. Wolstencroft E (2002). Talent Identification and Development: An Academic Review. Edinburgh: Sportscotland.

1.2 RATIONALE FOR THE DEVELOPMENT OF THE FLEMISH SPORTS COMPASS

This second chapter describes the methods used in the development of the Flemish Sports Compass in a condensed form. The project is too extensive to discuss all details, due to the different sports and methods used. For a full and detailed description we refer to Lenoir & Pion (2011). The 'Flemish Sports Compass' was conducted in a relatively short time period (2007-2010) using valid and reliable tests and measurements for different target groups. Representative data were collected in primary schools (6-12y), elite sports schools (12-18y) and different sports federations (9-21y). The usability of the different methods was tested and later applied in the different original studies in the second part of this dissertation.

Talent identification programs are implemented worldwide to identify the better athletes at an early stage. Best practices in talent detection and talent identification over the last decades can lead to new insights in this area. A talent detection and identification system cannot be implemented "out of the blue". There is a need for accurate data on morphological, physical, coordinative and maturity characteristics. Talent identification is a dynamic process and should take into account the maturity status and the potential to develop, rather than to exclude children at an early age (Vaeyens et al., 2008).

Cross-sectional talent identification models are likely to exclude many children although for talent detection a brief test battery provides opportunities for recommendations to move children towards a sport based on the characteristics that were measured. The advantages of a generic screening are multiple. Children who have not yet started their sports training can be orientated on objective data to one or more sports and promising athletes of various ages can be guided throughout their development. Indeed, a second and third measurement will reinforce earlier data and the longitudinal interpretation of the data is more appropriate for talent identification although a first impression can provide useful information for talent detection purposes.

The aim of this study is to facilitate the sport choices made by both, the future athlete and the sports organisations. Small countries have difficulties to compete with the traditional nations that lead in the medal rankings. A disadvantage for small countries is that the sports clubs may not miss a single talent. The detection of the 'better mover' is the first phase in an optimal talent system that collects generic information that is usable for all sports bodies. The concept 'better mover' is broader than the purely motor meaning that one can draw from this expression. Talent detection is meant to detect children who are suitable for sports in general. This is the reason why the Flemish Sports Compass takes into account physical characteristics, anthropometric measurements and motor coordination, to detect the 'better movers'.

Making an overall assessment is less popular in a sport-specific environment and the expenses incurred cannot be converted immediately into sports-specific success. The cost benefit analysis indicates that testing many children is expensive. This weakness however can be conversed in an advantage because the country is small enough to screen each child. There have already been attempts to develop talent identification systems i.e. Australia and Scotland, but for large countries, the scope of such a project is too big. Small countries can reverse their disadvantages into an advantage by not skipping this step in their talent policy.

Most research questions in talent identification arise from the perspective of sports clubs and federations. Their aim is to select young potentials based on sport specific talent characteristics. The fragmented approach of all the different organisations is highly disadvantageous in a small country and therefore a generic test battery could be the solution for the detection phase. The test battery should provide information to both, athletes and clubs. On the one hand the selection of the most suitable athletes for the clubs and on the other hand the most appropriate sport(s) for each individual should be interpreted from the results. To what extent can generic talent characteristics assist in the orientation towards a sport that suits with individual qualities?

The design of the Flemish Sports Compass implies a broad knowledge about different sports. The different research targets that interact with each other are to be combined in one single test battery i.e. “The Flemish Sports Compass”. Either for a) the detection of the ‘better movers’ in the primary schools, b) the identification of the better athletes in different sports federations and c) the orientation towards a sport that best fits, was chosen for the same generic tests in this test battery. To transform the criterion into objectively measurable aspects, a complex construct of tests and measurements, were retrieved from literature. Additionally, sports coaches indicated the importance of the necessary characteristics for their respective sports. Evaluating performance characteristics allows an orientation towards a sport that meets the individual strengths. If the detection of the ‘better movers’ is important for elite sport, simultaneously the detection of the strengths is important for all children to motivate them towards an appropriate sport.

1.2.1 PATHWAYS FOR A TALENT SYSTEM IN FLANDERS

THE ADDED VALUE OF TALENT DETECTION IN SMALL COUNTRIES

The talent system to be implemented in Flanders should have the ambition to screen every child. It is important to determine the different opportunities for the implementation of a talent system in a small country. Two previous attempts to implement talent detection in a talent system were not successful. Due to the magnitude of the country and the perspectives of different sports it was difficult to complete the initiatives for talent detection in Australia and Scotland. Both countries started with a detection phase, which turned over in new standards for talent identification systems. The detection phase is based on the assumption that the performance characteristics for future sports success is already detectable at a young age. The overall approach for different sports is quite difficult and in this research area there are few objective data, which entails a certain resistance to such large-scale projects. There is a consensus that talent detection is the first phase in an optimal talent system. In different talent identification systems all over the world, the first assessment is the collection of generic information. In our opinion this phase used by all sports bodies can be coordinated to a specific detection phase. The overall assessment is less popular in a sport-specific environment because sports managers believe that the expenses incurred cannot be converted immediately into sports-specific success. The cost benefit analysis is approached from the perspective that testing many children is expensive. This approach is not entirely correct because the costs incurred by the sum of all sports federations rise much higher than a joint initiative. The attempts to develop talent identification systems in Australia and Scotland had the negative connotation that the scope of the project was too big. How about small countries, will they be able to reverse the disadvantages into an advantage by not skipping this step in their talent policy? The generic assessment meets the needs of all sports federations and can be considered as the first phase in a sliding population approach. All instances can be considered as partners, with a common database. The fear of predatory behaviour among the sports federations can be invalidated by the correct orientation of young high potentials that made the right choice at the right moment.

A GENERIC TEST BATTERY AS A BASIC CONCEPT

Talent identification test batteries have specific aims for one specific sport. Indeed, when consulting the literature it is clear that those specific test batteries rely on field tests, which assess the demands of that specific sport. Remarkably the same tests are retrievable in specific test batteries for other sports. Indeed, speed and agility are required in almost every sport still the outcome is not always intended for the same purpose. The so-called generic tests examine the common characteristics that occur in different sports. Every sport is more or less specific and shows generic and specific characteristics. Yet, at our knowledge only one study of Leone and colleagues (2002) compared and distinguished different sports with a single test battery. The assumption that a generic test battery offers multiple advantages was the trigger to construct The Flemish

Sports Compass. The purpose was that this test battery could be used for talent detection, talent orientation and talent identification. The multiple applications have different aims. First the test results used for talent detection should indicate the difference between poor en excellent movers. Second the generic test results should have the power to orient children towards different sports and third some of the generic tests complemented with sport-specific tests should distinguish the poor and the better players in a certain sport when the aim is to identify talented players. The KTK might be of great use for displaying the gross motor coordination of a population, comprising the whole spectrum of children. The test not only distinguishes between normal and motor impaired children but also between normal and advanced children. Recent studies revealed that a lot of motor skills remain relatively stable with increasing age (Ahnert et al., 2009; Vandorpe et al., 2011). The stability of motor abilities is important across the field of talent selection and talent development and the early detection of 'better movers'. Vandorpe and colleagues sugest that children with an MQ above 115 receive further guidance in sports to develop their talent.

THE QUALITY OF THE 'FLEMISH TALENT POOL'

Most federations rarely search for talent in the group of children who did not yet choose for a sport. Whether it is efficient is doubtful because the different sports federations do not cooperate in their common challenge. It is worth considering at least addressing the phase of talent detection with all concerned partners. Recent research has shown that the amount of potential future athletes in all the Flemish sports federations becomes systematically smaller. It has been demonstrated that the physical properties of Flemish youth (strength, speed, endurance, flexibility) as in other industrialized, but even in third world countries has declined. The same trend occurs in the area of motor coordination, which is the corner stone for efficient learning and performing specific techniques. Vandorpe et al. (2011) found that the percentage of gifted children has halved in terms of gross motor coordination in the last three decades, while the number of children with motor problems has doubled. Therefore, it is important to take initiatives to address the problem of talent search at the base. The policy makers hold the opportunity of a coordinated action since most federations recognize talent when an athlete happens to end up in their certain sport. The talent system usually starts with the talent identification, the search of the most gifted in a population that has already opted for a specific sport. The question that arises is whether we can assume if potential athletes should be detected by accidental circumstances? "Bloso" implemented previous actions in Flanders with the primary aim of sports promotion i.e. "De Bloso Jeugd Olympiade". Unfortunately, the obtained data were not used for scientifical purposes. The organisation of such a large-scale event offers more possibilities than what was customary.

1.2.2 METHODOLOGY OF THE FLEMISH SPORTS COMPASS

The preliminary studies of the Flemish sports compass took into account the six phases framework suggested by Régnier et al. (1993).

- Determining the criterion
- From criterion to measurements
- Determining the methods
- Data collection
- Statistical methods and benchmarks
- Validity of the different profiles

PHASE 1: DETERMINING THE CRITERION

The talent detection comprises the measurement and comparison of values that determine the sport specific performance. The criterion is easy to define in sports characterised by an outcome in m, kg and s (ex. 100m sprint). In team sports or tactical sports it is much more difficult to provide a single criterion related to performance (ex. soccer, fencing). Talent research mostly focuses on differences between elite and sub-elite. To filter out the talent characteristics, researchers often compare different age groups or performance levels in a cross-sectional design. The attributes that reveal the most significant differences between performance levels are determined to be discriminate or predictor variables (Breitbach et al., 2014). Different sports show similar movements, resulting in the same generic tests. Even though the aims of the tests are different (detection - identification - selection - orientation). For each target, the criterion measure will therefore be different. A distinction will be made between the criteria used for talent detection, which searches for the 'better movers' and also the criteria for talent identification, which searches for the better (discipline-specific) sportsmen. Furthermore, the use of generic tests and measurements allow indicating differences between sports. Most talent research applying generic field tests, focusses on differences between elite and non-elite: Badminton: (Ooi Cheong Hwa et al., 2009), basketball: (Jaric et al., 2001), (Bale, 1991), gymnastics: (Vandorpe, 2011), (Bencke, 2002), handball: (Mohammed, 2009), (Zapartidis, 2009), (Lidor, 2005), judo: (Monteiro, 2001), rugby: (Gabett, 2009), (Booysen, 2008), fencing: (Tsolakis, 2010), (Nystrom, 1990), volleyball: (Gabett, 2007), (Duncan, 2006), waterpolo: (Falk, 2004), swimming: (Kavouras, 1992).

Table 1: Example of consulted studies for 3 sports in the Flemish Sports Compass (2007-2012).

Authors	Height	Sitting Height	Weight	BMI	Body Fat	Global flexibility	Shoulder flexibility	Horizontal jump	Vertical jump	Sprint 5m	Sprint 30m	Shuttle run	Abdominal strength	Shoulder strength	Endurance	Balance	Jump agility	Global agility	Dribble run	Dribble hands	Dribble feet	Throwing
Badminton	■		■	■	■			■	■	■	■	■			■	■		■				■
Chin et al. (1995)															x							
Majumdar et al. (1997)	x		x		x										x							
Amusa et al. (2001)	x		x	x	x																	
Manrique et al. (2003)	x		x	x											x							
Wonish et al. (2003)	x		x	x											x							
Hughes (2003)									x			x										
Faude et al. (2007)															x							
Ooi et al. (2009)	x		x	x	x			x				x			x							
Campos et al. (2009)	x		x	x	x			x	x		x	x	x		x							x
Werkiani et al. (2012)	x				x					x	x					x		x				
Basketball	■	■	■	■	■	■			■	■	■	■	■		■				■	■		■
Bale (1991)	x		x	x	x				x													
McClay et al. (1994)												x							x			
Hoare et al. (2000)	x	x	x	x		x			x	x		x	x									x
Jaric et al. (2001)	x		x	x																		
Karpowicz (2006)	x																					
Drinkwater et al. (2008)	x		x		x				x		x	x			x							
Ziv et al. (2009)	x		x		x				x	x	x				x							
Abdelkrim et al. (2010)	x		x	x	x					x	x	x			x				x	x		
Gymnastics	■	■	■	■	■	■	■	■	■	■	■		■	■		■	■	■				
Bajin (1987)								x	x		x		x	x								
Singh (1987)						x	x		x				x									
Sol (1987)							x		x		x			x		x						
Grabiner & McKelvain (1987)									x				x	x								
Petiot (1987)	x	x	x	x	x																	
De Albuquerque & Farinatti (2007)						x	x	x	x		x			x		x		x				
Zuniga et al. (2011)	x		x	x	x																	
Sleeper et al. (2012)	x		x			x			x		x			x								
Vandorpe et al. (2011)	x	x	x	x	x	x	x	x	x	x	x		x	x		x	x	x				

Criterion and Target group

The criterion depends on the target group for which the test battery is used. The scores of the talent characteristics are valuated by age and gender and normalized to the sample. Matsudo (1987) applied z-scores for anthropometric and performance characteristics while Kiphard and Schilling (2007) applied motor quotients (MQ) to determine the motor competence.

Normalized scores indicate how far a test result is positioned from the average score within the tested population. This approach is useful for both the comparison of age groups and the comparison of different sports. The distinction between different populations is demonstrated by the following example. An average score for a girl compared to her peers in the primary schools is different to an average score for the same girl compared to her peers in a sub-elite sports club (Figure 5).

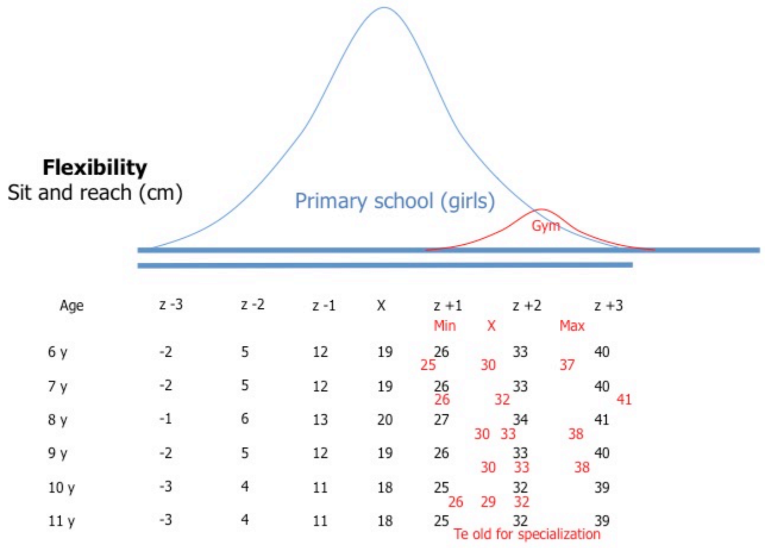


Figure 5: Raw scores compared to target group (Detection in primary schools vs. Identification in gymnastics)

The use of a generic test battery in different target groups allows extrapolating normalized scores into a different context. Normalized scores indicate where a boy or girl can be located compared to a sport specific setting or compared to primary school children or young athletes in the Flemish elite sport schools.

PHASE 2: FROM CRITERION TO MEASUREMENTS

The assumption that two athletes of different levels can be distinguished from each other based on specific characteristics which influences their performances is a premise already mentioned in the first chapter of this dissertation. The data were collected in various ways such as task analysis, a literature review and surveys or by conducting measurements in elite athletes. Different physical and motor test batteries have been tested in the initial phase of the 'Flemish Sports Compass – project'. A number of test batteries and isolated test items were selected based on the literature and on the experience gained by members of the Movement and Sports

Science Department of the University of Ghent in conducting various test batteries at different target children and adolescents.

Criterion

The validity and reliability to conduct the selected tests were important aspects given the large number of children evaluated by different test leaders. The ease of the instructions, the complexity of the scoring system, the usefulness of the equipment and the time required to conduct the test were taken into account in the selection of the tests for the 'Flemish Sports Compass'

Objectivly measurable aspects

The physical characteristics show clear differences between sports and therefore it is necessary that some basic anthropometric measurements and a few items from the Eurofit test battery (Council of Europe, 1988) are included as a basis for the generic test battery of the Flemish Sports Compass. After reviewing possible testitems it was decided to ad motor competence tests. The assessment of motor coordination often depends on complex test batteries. Several pilot studies using the Movement Assessment Battery for Children (MABC) a test battery used worldwide mainly for clinical diagnostic settings have demonstrated that this test battery differentiates within the motor weaker children, but not between the skilled and highly skilled children (Smits-Engelsman et al.; 1998; Schoenmaecker et al.; 2003; Van Waelvelde at al., 2004). The MABC was not adopted because it did not meet the requirements for talent detection. Other tests (such as BOT – long form) are time consuming (> 40 minutes) and complex test material. Finally, the BOT2 - shortform

Table 2: Flemish Sports Compass evolution (2007 to 2015)

PRELIMINARY STUDIES 2007-2009	PRELIMINARY STUDY Original test battery (2007)	PRELIMINARY STUDY TEST REDUCTION (After Factor analysis 2008)	PRELIMINARY STUDY Elite Sports Schools 2008-2010	TALENT ORIENTATION Study 1 (25 sports)	TALENT ORIENTATION Study 2 (9 sports)	TALENT ORIENTATION Study 3 (martial arts)	TALENT IDENTIFICATION Study 4 (elite volleyball)	TALENT IDENTIFICATION Study 5 (Gymnastics / survival)	TALENT IDENTIFICATION Study 6 (Gymnastics / neural networks)	SPORTS COMPASS 2015
n=5.613	n= 2.926	n= 2.926	n=1.411	n=620	n=141	n=56	n=23	n=243	n=243	
ANTHROPOMETRY										
Stature	X	X	X	X	X	X	X	X		X
Sitting height	X	X	X	X	X	X		X		X
Weight	X	X	X	X	X	X	X	X		X
Fat%	X	X	X	X	X	X	X	X		X
BMI (calculated)	X	X	X	X		X		X		X
Hip circumference	X	X								
PHYSICAL PERFORMANCE										
Sit and reach	X	X	X	X	X	X	X	X		X
Shoulder rotation	X	X	X	X	X		X			X
Hand grip	X	X	X		X	X	X			X
Standing broad jump	X	X	X	X	X		X			X
Knee push-ups	X	X	X	X	X		X	X	X	X
Curl-ups	X	X	X	X	X	X	X	X	X	X
Shuttle run	X	X	X	X	X		X			X
Endurance shuttle run	X	X	X	X	X					X
Counter movement jump (height)	X	X	X	X	X	X	X	X	X	
Counter movement jump (power)	X	X	X							
GROSS MOTOR COORDINATION										
Balancing backwards KTK	X	X	X	X	X	X	X	X		X
Jumping Sideways KTK	X	X	X	X	X	X	X	X	X	X
Moving sideways KTK	X	X	X	X	X	X	X	X		X
Hopping for height KTK	X	X						X	X	
FINE MOTOR COORDINATION										
Drawing lines (BOT2)	X									
Folding paper (BOT2)	X									
Copying a square (BOT2)	X									
Copying a star (BOT2)	X									
Transferring pennies (BOT2)	X									
Jumping in place synchronised (BOT2)	X									
Tapping feet and fingers (BOT2)	X									
Walking forward on a line (BOT2)	X									
Standing on one leg on a balance beam (BOT2)	X									
One-legged stationary hop (BOT2)	X									
Dropping and catching a ball alternating (BOT2)	X			X						X (U9)
Dribbling a ball alternating hands (BOT2)	X									
ADDITIONAL GENERIC TESTS										
Sprint 5m			X		X	X	X			
Sprint 30m			X		X	X	X	X (20m)	X (20m)	
Throwing shuttles			X		X		X			
Dribbling (run)			X		X					
Dribbling (hands)			X		X		X			X
Dribbling (feet)			X		X					
Tanner Index								X		
Rope skipping 60s								X	X	
Basic motor skills								X	X	
41 tests	32 tests	20 tests	24 tests	17 tests	22 tests	14 tests	18 tests	17 tests	8 tests	17 tests

(Bruininks and Bruininks, 2006) and the KTK (Kiphard and Schilling, 2007) were selected for the assessment of the motor competence. In the preliminary studies, 41 tests were selected for different assessments Table 2. The first assessment in the primary schools in 2007 consisted of 32 elementary field tests Based on the usability from the tests in the secondary schools and the results of the factor analysis; the test battery was redeveloped and contained 20 tests. In 2008, 24 tests test were applied in the Flemish elite sports schools. The hopping for height test was retained due to the risk of injuries and the hip circumference due to the few added value. Subsequently the collected data were processed as reference for talent identification programs in different sports federations. In 2015 the test battery was reduced to 17 test items for talent detection in the schools. The criteria to reduce the test battery to a tool for talent detection in schools, were time and cost. Therefore, electronic devices and time consuming assessments were restricted from the test battery. The detection test battery used in the primary schools is also the basis for sport specific talent identification test batteries.

The use of the same tests for talent detection as well as for talent identification is advantageous for the comparison of data. For talent identification the applied tests should also meet sport specific requirements. Therefore, some of the generic tests with low sport specific relevance are omitted and replaced by sport specific field tests (**Fout! Verwijzingsbron niet gevonden.** and **Fout! Verwijzingsbron niet gevonden.**).

PHASE 3: DETERMINING THE METHODS

The Flemish Sports Compass consisted of 41 valid, reliable and objective generic tests. These field tests corresponded to the requirements to test a group of children and /or athletes in a relatively short time-span with a minimum of equipment. After the first year the different generic tests were evaluated by means of a factor analysis with the intention to reduce the number of tests in the testbattery. A factor analysis (Varimax, Kaiser normalisation) realigned the data from the different tests, obtained in the primary schools. Using this technique allows to quantify the importance of each component and the contribution of each variable in the construct of the Flemish Sports Compass. The 32 tests and measurements conducted in the primary schools were divided into seven factors (Table 3). The minimum load factor was 0.30. The analysis resulted into seven factors instead of the three originaly defined factors (anthropometry, physical fitness and coordination).

Factor 1: Physical fitness and motor coordination

Counter movement jump (heigth), Hopping for heigth KTK, *Standing broad jump*, *Shuttle run*, *Counter movement jump (power),* Jumping sideways KTK, Moving sideways KTK, *Endurance shuttle run*, *Handgrip*, *Sit-ups BOT-2*, Walking Backwards KTK, *Knee push-ups BOT-2*, Bal dribble BOT-2, Transferring pennies, One-legged stationary hop BOT-2 have factor loadings above .30. The tests related to Physical fitness are mentioned in italics.

Factor 2: Anthropometry

The factor load for Weight, *BMI*, *Hip circumference*, F*atpercentage*, *Sitting heigth*, *Stature and Handgrip* is over .30. The Handgrip test correlates with weight although; it is possible to subdivide this test with the physical characteristics with a loading also above .30 for factor 1.

Table 3: Factor analysis for the generic tests conducted in the primary schools.

Test	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
KTK (MQ)	0,494	-0,368	0,461		0,358		
Stature (cm)	0,537	0,637			-0,342		
Mass (kg)		0,944					
BMI		0,925					
Body Fat (%)	-0,502	0,74					
Hip circumference (cm)		0,923					
Sitting height (cm)	0,488	0,645					
Sit and reach (cm)					0,786		
Sholder rotation (cm)					-0,668		
Shuttle run 10x5 m (s)	-0,749		-0,352				
Counter movement jump (cm)	0,833						
Counter movement jump (watt)	0,683						
Standing broad jump (cm)	0,818						
Handgrip (kg)	0,613	0,583					
BOT 2			0,45	0,631			
Knee push-ups BOT 2 (n/30s)	0,507		0,446				
Sit-ups BOT 2 (n/30s)	0,583						
Drawing lines BOT 2						-0,373	0,398
Folding paper BOT 2				0,365		0,349	
Copying a square BOT 2				0,75			
Copying a star				0,744			
Transferring pennies BOT 2	0,407					0,31	
Jumping in place synchronised BOT 2						0,609	
Tapping feet and fingers BOT 2						0,699	
Walking forward on a line BOT 2							0,797
Standing on one leg on a balance beam BOT 2			0,499				
One-legged stationary hop BOT 2	0,31		0,613				
Dropping and catching a ball alternating BOT 2				0,353			
Dribbling a ball alternating hands BOT 2	0,434		0,374				
Walking backwards KTK (n)	0,542		0,417				
Moving sideways KTK 2x(n/20s)	0,654		0,402				
Jumping sideways KTK 2x(n/15s)	0,69		0,447				
Hopping for height KTK	0,83		0,333				
Endurance shuttle run (min)	0,643						

Factor 3: Gross motor coordination

The following measurements have load factor over .300: *One-legged stationary hop BOT2, Standing on one leg on a balance beam BOT2*, *Jumping sideways KTK, Knee push-ups BOT 2, Walking Backwards KTK, Moving sideways KTK, Dribbling a ball alternating hands BOT2,* Shuttle run and *Hopping for heigth KTK*. De tests mentioned in italics represent gross motor coordination. The shuttle run loaded higher for the first factor.

Factor 4: Fine motor Coordination 1

Copying a square BOT2, Copying a star BOT2, folding paper BOT2 and dropping and catching a ball alternating BOT2.

Factor 5: Flexibility

Sit and reach and Shoulder rotation.

Factor 6: Fine motor Coordination 2

Tapping feet and fingers BOT2, Jumping in place synchronised BOT2, Drawing lines BOT2 and Transferring pennies BOT2.

Factor 7: Fine motor Coordination 3

Walking forward on a line BOT2 and Drawing lines BOT2.

In conclusion: the seven factors obtained in this factoranalysis are in line with the postulated model of anthropometric, physical and motor coordination tests. The seven factors can be reduced to four factors mostly described in literature as physical fitness; anthropometry; gross motor coordination and fine motor coordination. Therefore, factor 1 should be subdivised in physical fitness tests and supplemented with factor 5 i.e. the flexibility tests. Factor 2 represents the anthropomteric measurements and factor 3 the gross motor coordination. Finally factor 4, 6 and 7 can be combined to form the factor fine motor coordination (Table 3).

PHASE 4: DATA COLLECTION

Primary schools

A longitudinal study design was conducted to gain insights into the longitudinal development of anthropometric physical and coordinative characteristics. During the first year of the testing (2007), 29 elementary schools were randomly selected from all five provinces of the Flemish and the Brussels – capital region. To ensure a representative sample of the school-aged children, stratification based upon education type (special/normal), geographic area (rural/city) and school system (Catholic, governmental, provincial/city) was taken into account. Thirteen schools approved to participate in the longitudinal assessment of their pupils. In 2007, 2926 children completed the Flemish Sports Compass test battery. In 2008, thirteen schools approved to participate in the longitudinal assessment of their pupils, 1457 children (of which 954 already tested in 2007) completed the testbattery and during the 3rd consecutive year of testing, 1230 children (of which 712 already tested in 2007 and 2008) were tested. From this sample of 712 follow-up pupils, only the children six years or older and younger than 12 and those who completed the assessment annualy were retained for the longitudinal study resulting in a total of 638 children (327 girls and 356 boys). In 2007, the cohort was aged 6-9 years (8.3 +/- 1.1 years), maturing to 8-11 years of age (10.3 +/- 1.1 years) in 2009 (Vandorpe et al., 2011). The small sample that completed the test battery for three consecutive years were part of a randomly selected sample and turned into a smaller sample formed by chance in which the original stratification was no longer valid.

Flemish elite sport schools

A Cross sectional data collection was obtained in the Flemish elite sport schools from 2008 to 2010 The participation of the schools was obtained with the coöperation of the Flemish Government (Bloso). The 428 girls and 983 sport students were 12 to 18 years old and represented 16 Flemish elite sport schools. Badminton, 18 girls and 39 boys; basketball, 77 girls and 119 boys; cycling, 10 girls and 52 boys; fencing, 6 girls and 16 boys; golf, 10 girls and 28 boys; gymnastics 49 girls and 57 boys; handball, 44 girls and 107 boys; judo, 23 girls and 40 boys; soccer, 21 girls and 345 boys; Swimming 19 girls and 15 boys; taekwondo 7 girls and 3 boys; table tennis, 2 girls and 18 boys; tennis, 18 girls and 25 boys; track and field, 84 girls and 37 boys; triathlon, 7 girls and 29 boys and volleyball 33 girls and 53 boys.

Flemish Sports Federations

The collaboration with fifteen Sports Federations fitted partially within the second “Sports Action Plan Flanders (2009-2012)”. For which, a strategic objective was to realise a talent identification testbattery in each sports federation. The collaboration with the sports federations resulted in test batteries for different sports, i.e. track and field (since 2009, n = 614), badminton (since 2008, n = 192), gymnastics (since 2008, n = 756), handball (since 2008, n= 640), ice-skating (since 2008, n= 50), judo (since 2008, n = 245), fencing (since 2008, n = 238), ski (since 2008, n=111), taekwondo (since 2009, n= 48), tennis (since 2008, n = 58), triathlon (since 2009, n = 211), soccer (since 2007, n = 7533), volleyball (since 2008, n = 2286), cycling (since 2008, n= 290) and swimming (since 2013, n = 211). Specific talent identification systems were developed in concert with the different sports federations. The main part of the test battery consisted of generic tests with reference data from the Flemish Sports Compass supplemented with sport specific tests. The 16 tests for ‘talent detection’ of the Flemish Sports Compass 2015 are presented in (Figure 6). The test batteries, wich were developed for talent identification were based upon the generic tests of the talent detection test battery and the tests with low relevance for that specific sport were not retained in the talent identification test battery (Figure 7). The Flemish Sports Compass is broader than a talent detection test battery that contains different generic tests. The test battery (or a part of) can also be implemented in different sports for talent identification purposes. Therefore, the generic tests with low relevance (such as dribbling for gymnastics) can be replaced by more sport specific assessments.

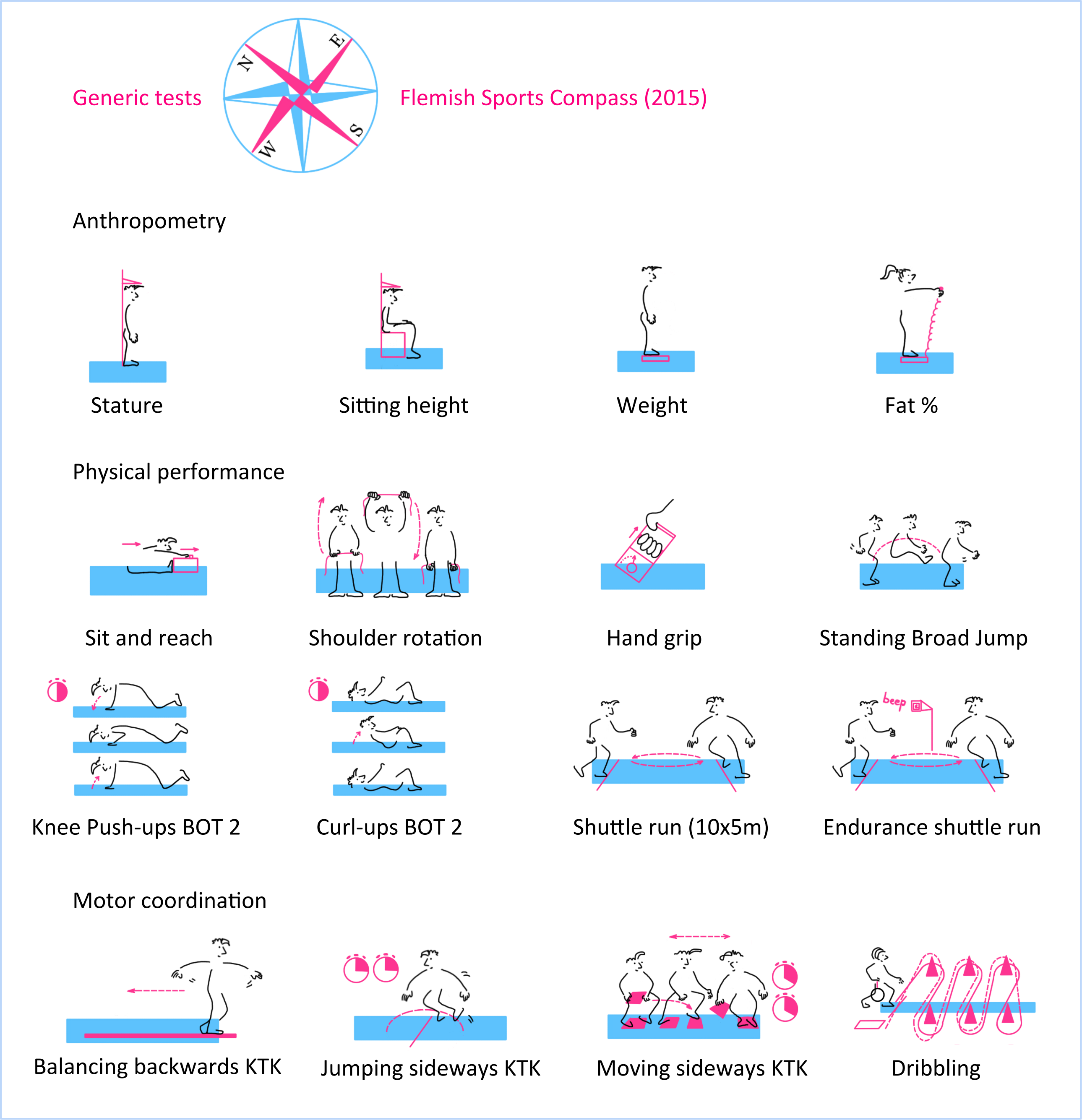


Figure 6: Generic tests for 'Talent Detection' Flemish Sports Compass (2015)

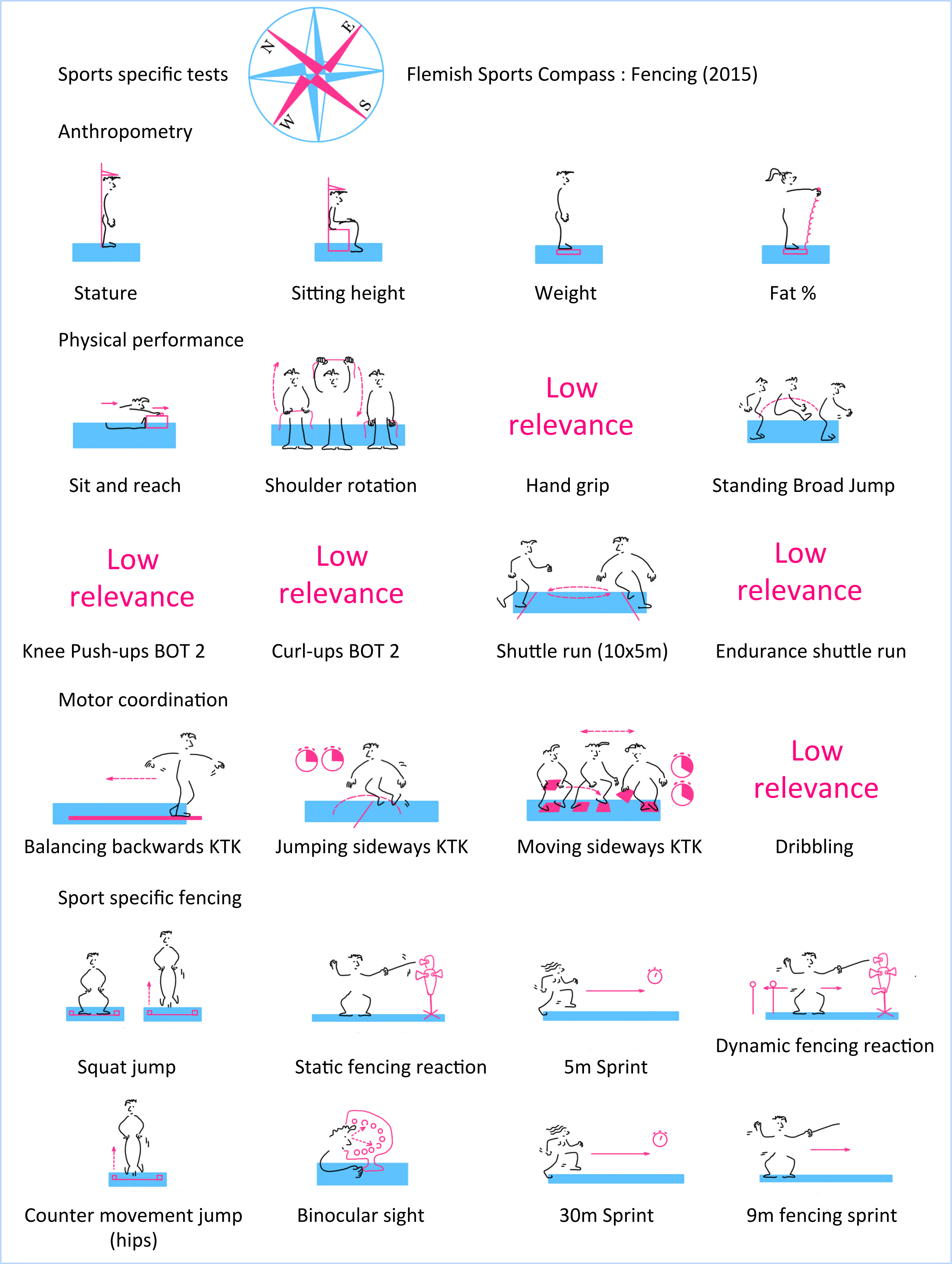


Figure 7: Generic tests for 'Talent Identification in fencing' Flemish Sports Compass (2015)

PHASE 5: STATISTICAL TECHNIQUES AND BENCHMARKS

Test scores

What is the meaning of a raw score of 1.76 m? When interpreting test results, raw scores do not mean much, unless they can be compared to other scores. 1.76m might be the stature of a 12y old girl or a 16y old boy and it can even be the distance measured with a standing broad jump from a 17y old girl or a 9 year old boy. The interpretation of test result 1.76m becomes even more complex when interpreting the stature from a late and or an early mature badminton player for a standing broad jump. Gifted athletes are often indicated by excellent (unusual) test scores. Therefore, it is important that the normal scores are benchmarks for talent detection. Matsudo (1996) implemented the Z-score strategy to detect exceptional scores for volleyball and basketball players. His system was based on the Z-profile of a talented sportsman compared to the Z-profile of elite players in the natonal team in a certain sport. The Z-strategy from Matsudo (1996) was adapted and recalculated into motor quotient scores (MQ) by Kiphard and Schilling (2007) and later by Ahnert (2009) who aimed positioning children for motor coordination. The main difference between Z-score and motor quotient scores is that the scores are expressed in positive scores compared to the positive and negative Z-scores. The motor quotient equals 100 + ((score - mean score) / standard deviation) x15). This shows that the motor quotient is a conversion of the Z-score to a scale in which the average is equal to 100 (Figure 8).

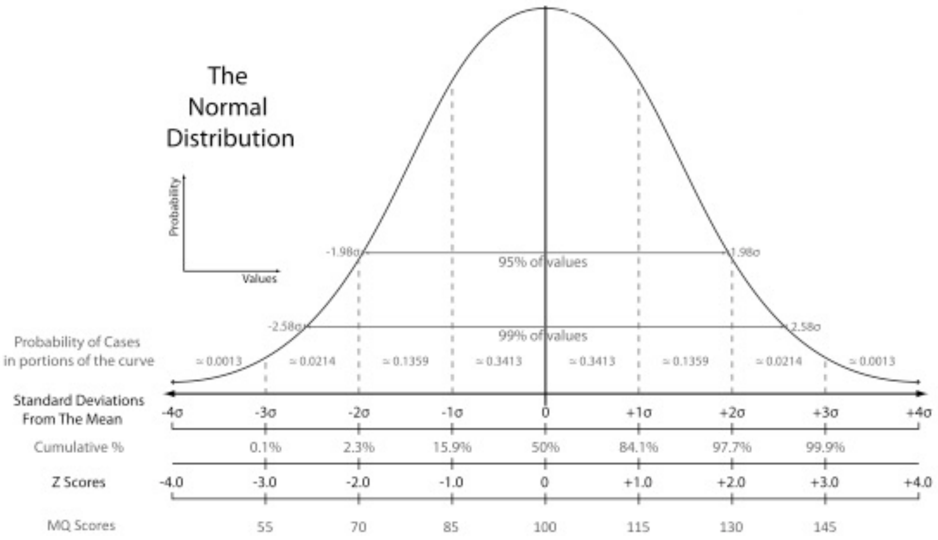


Figure 8: Positioning with Z-scores and MQ scores

From 2007 to 2009, 5.613 children (6-12y) and 1.411 adolescents (12-18y) from 16 different Flemish elite sports academies performed the Flemish Sports Compass test battery. Parallel to the study of the Flemish Sports Compass data were collected for talent identification in different sports with a mix of generic and sport specific tests, which serve as benchmarks for different populations, and different sports.

The preliminary studies based on the descriptive data approach of the Flemish Sports Compass devotes attention to 1) the interpretation of raw scores and normalised scores 2) The lines of development for talent characteristics 3) Linear extrapolations from raw scores to normalised scores and back to raw scores 4) Sports profiles based on MQ scores 5) MQ scores and maturity status.

The use of raw scores

The measurement obtained from a certain test equals 1.76. This measurement is clear although its interpretation is difficult. The context is important to decide whether this score is promising for the elite level in a certain sport.

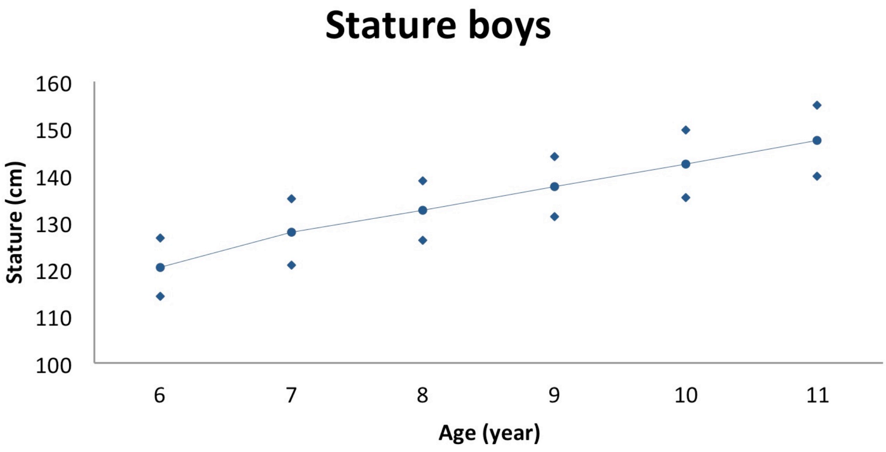


Figure 9: Stature from primary school boys (Benchmark: Flemish Sports Compass 2007-2009)

The raw scores were applied in a one-way ANOVA i.e. 2 (gender: boys vs. girls) x 6 (age) in order to explain the differences in development of the stature between girls and boys. Based on the results of the preliminary study conducted in 3592 primary school children, we can conclude that the development curves for stature in 6 to 11year old boys and girls run similar. There is no significant interaction effect between age and gender (F = 1.805 and p = .071). The stature increases significantly with age (F = 758.038, p < .001), and there are no significant differences between boys and girls (F = 3.301 and p = .069).

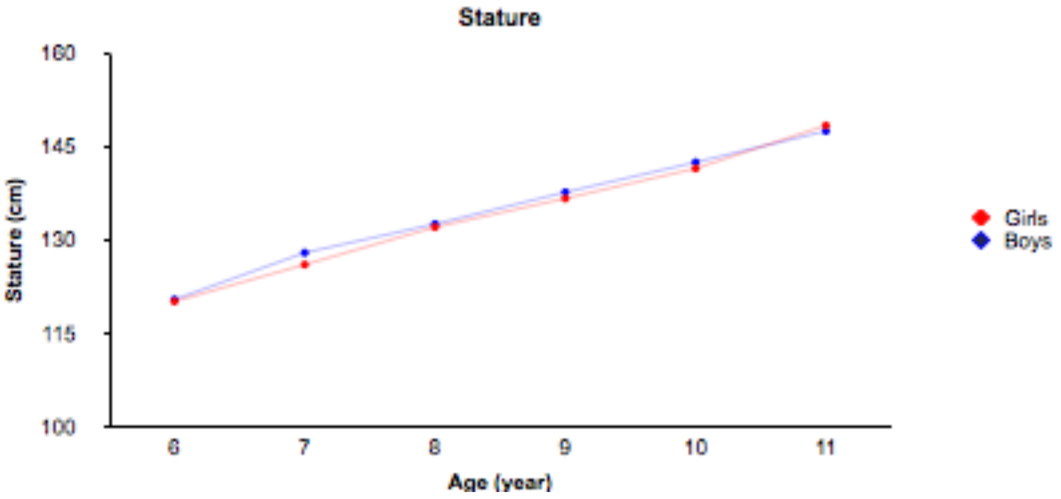


Figure 10: Differences for stature between boys and girls (Benchmark: Flemish Sports Compass 2007-2009)

The benchmarks for the boys in the primary schools are presented in Table 4.

Table 4: Raw scores Flemish Sports Compass Boys (mean and standard deviation)

Measurement	Boys 6y	Boys 7y	Boys 8y	Boys 9y	Boys 10y	Boys 11y
Stature (cm)	120,4 ± 6,2	127,9 ± 7,1	132,5 ± 6,3	137,6 ± 6,4	142,4 ± 7,2	147,4 ± 7,6
Weight (kg)	23,2 ± 4,3	26,9 ± 6,2	29,3 ± 5,8	32,4 ± 6,7	36,1 ± 7,6	39,7 ± 8,5
Fat% (%)	19 ± 3,4	18,4 ± 5,1	17,4 ± 4,9	17,2 ± 5,3	17,2 ± 6,3	17,2 ± 6,8
BMI (kg/m2)	15,9 ± 1,7	16,3 ± 2,3	16,6 ± 2,3	17,0 ± 2,5	17,7 ± 2,9	18,1 ± 3,1
Handgrip (kg)	13 ± 3	15 ± 4	17 ± 4	20 ± 4	22 ± 4	24 ± 5
Curl-ups (n/30s)	11 ± 7	16 ± 8	19 ± 7	21 ± 7	22 ± 7	25 ± 7
Knee Push-ups (n/30s)	19 ± 7	21 ± 6	23 ± 6	24 ± 6	27 ± 6	28 ± 7
Standing broad jump (cm)	109 ± 19	125 ± 19	132 ± 19	138 ± 19	144 ± 20	151 ± 21
Shoulder rotation (cm)	85 ± 12	86 ± 16	87 ± 16	89 ± 15	93 ± 17	94 ± 18
Sit and reach (cm)	20 ± 5	20 ± 5	19 ± 6	18 ± 6	17 ± 7	16 ± 7
Shuttle run 10x5m (s)	24,9 ± 2,1	23,8 ± 1,9	22,9 ± 1,9	22,2 ± 1,6	21,9 ± 1,6	21,5 ± 1,6
Endurance shuttle run (min)	3,5 ± 1,5	4,5 ± 2	5,5 ± 2	6,0 ± 2	6,0 ± 2,5	6,5 ± 2,5
KTK balance beam (n)	25 ± 13	31 ± 13	36 ± 14	41 ± 14	43 ± 14	45 ± 15
KTK jumping sideways (n/(2x15s))	36 ± 11	46 ± 12	52 ± 11	59 ± 11	62 ± 11	67 ± 12
KTK moving sideways (n/(2x20s))	30 ± 6	35 ± 6	38 ± 7	42 ± 7	44 ± 7	46 ± 8

The use of development lines

The preliminary studies from the Flemish Sports Compass (2007 - 2011) were not only adapted for talent detection purposes. Some of the generic tests were integrated in sport specific talent identification test batteries (Figure 6 and Figure 7). The comparisons of the data for talent detection and talent identification can also be presented as development lines. Figure 11 demonstrates that the stature of female artistic gymnasts is under average compared to the sample of the primary school girls.

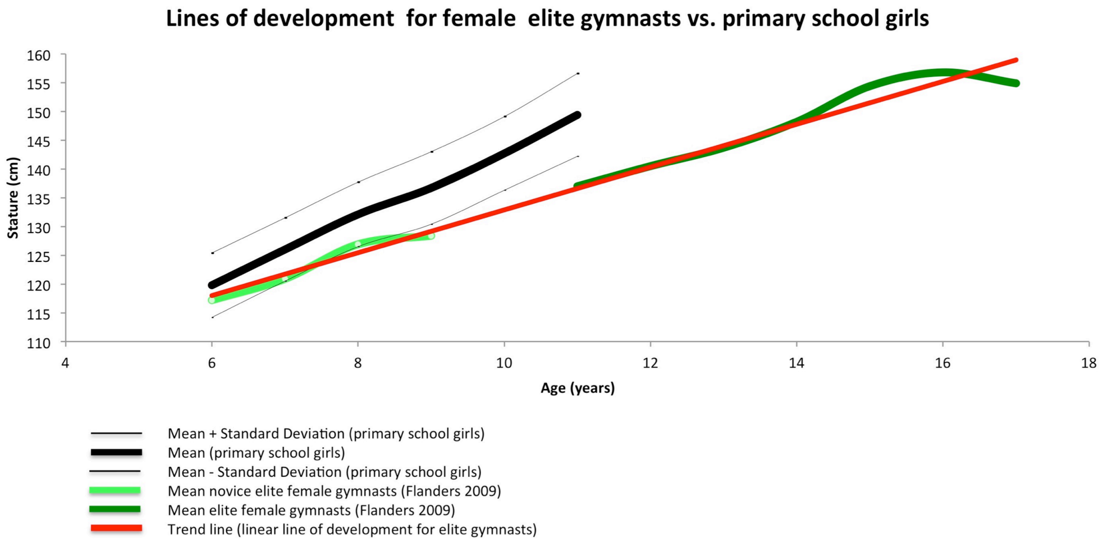


Figure 11: Development for stature in primary school children and female gymnasts

The use of Z-scores

The stature of an 11-year-old boy measuring 1.76m (Z-score = + 3.8) is a rather scarce phenomenon. However, adult volleyball and basketball players are tall when compared to a normal population with an average stature of 1.78m (SD = 0.08m) for men. In contrast a stature of 2.07m is recommanded for power forwards and centres in basketball or spikers, opposites and middle players in volleyball. Figure 12 demonstrates the normal distribution for each age group representing boys in Flemish elite sport schools. Each beam represents the scores between Z = -1 and Z = +1. The figure depicts how raw scores are converted into Quotient-scores. Referring to Kiphard & Schilling (1974), MQ scores for motor quotient; AQ scores for anthropometric quotient and PQ scores for physical quotient were applied in the different studies.

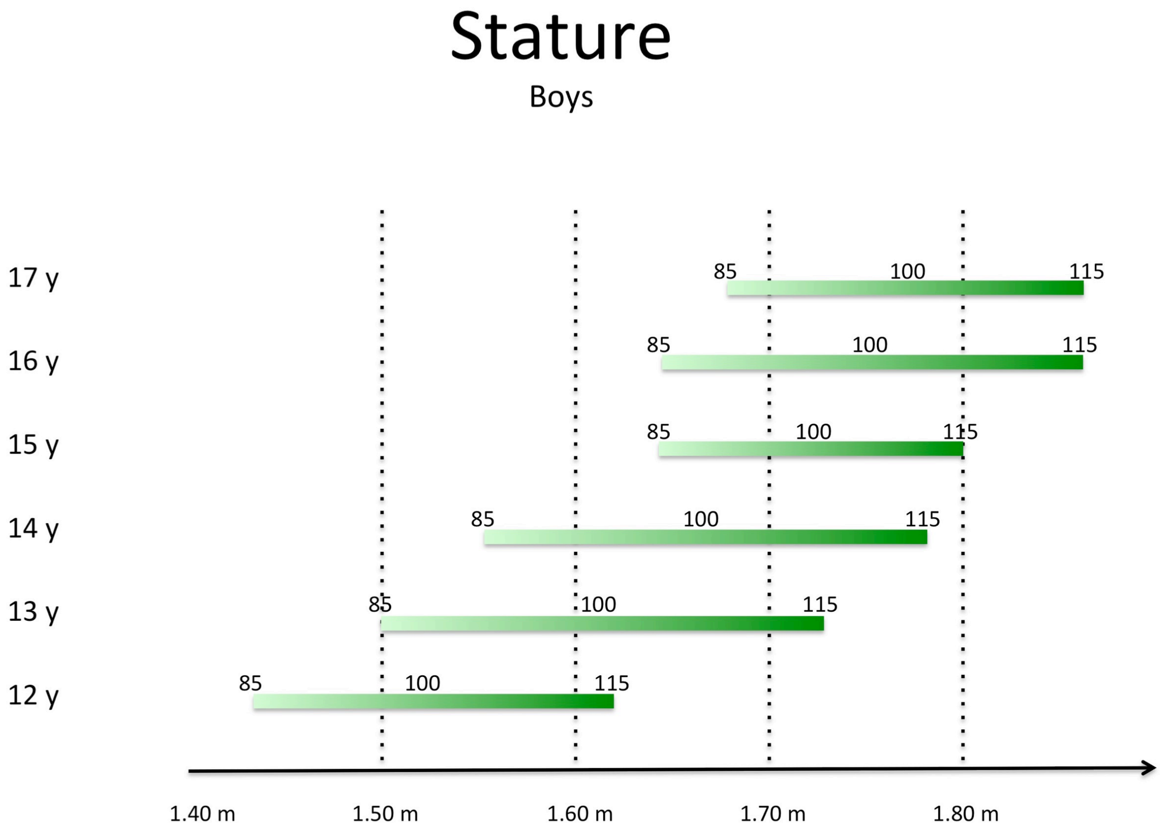


Figure 12: Body height (stature, AQ scores) from boys in Flanders Sports Academies (Benchmark: Flemish Sports Compass 2007-2009)

The use of quotient scores

When recalculating raw scores into quotient-scores for each talent characteristic it is possible to detect specific properties for certain sports. For example, a 9-year-old gymnast with a stature of 128 cm is small and comparable to a 15-year-old gymnast that measures 154 cm. The normalized AQ score for both boys is 85 benchmarked in the gymnastics population. In comparison to their peers at school they even score lower (AQ < 70). This example highlights the differences of the benchmarks for different purposes. When benchmarking for detection we might conclude that both boys are not gifted to play volleyball at the highest level. However, for talent identification in gymnastics they fulfill the required condition i.e. gymnasts are small (Figure 13).

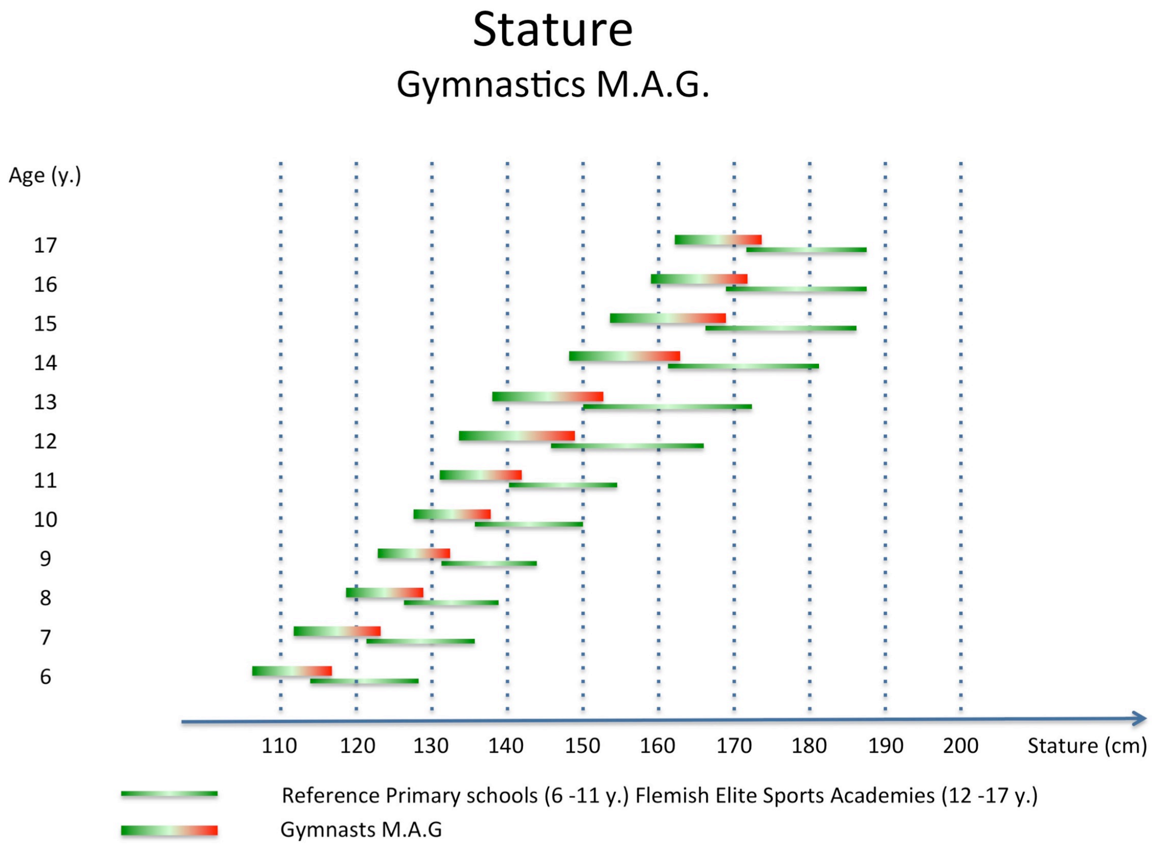


Figure 13: Comparing benchmarks for talent detection and talent identification

Note: The bar with the colour transition from a green (good) over white (average) to red (inferior) represents the population, which is within one standard deviation of the mean. The more a gymnast is taller, the more he moves towards the red side.

The preliminary investigations in the “Elite Sports Schools in Flanders” resulted in different sport profiles. The opportunity to conduct the same tests in all the sports academies was exceptional, although the generic test battery was not always perceived (by the trainers) as added value to the talent development in the elite schools. For each age group z-scores were converted into quotient scores (AQ; PQ and MQ). The differences between sports are difficult to investigate since the sample of elite-athletes is always small, otherwise the sample would not be called elite-athletes but over-average athletes. The best performers in each age group represent the elite for their sport in this preliminary investigation. This linear method is too straightforward to generalize these results for all athletes and therefore, other statistical methods should be conducted. An additional problem is that development lines run different for each talent characteristic and moreover they may also differ per person depending on the individual training level and maturity.

Table 5: Quotient scores for different sports in Flemish elite sport schools (mean and standard deviation)

Measurement	Gymnastics	Soccer	Badminton	Basketball	Handball	Judo	Fencing	Table tennis	Tennis	Triathlon	Volleyball
Stature	78 ± 11	96 ± 12	98 ± 10	114 ± 13	104 ± 12	89 ± 10	107 ± 15	99 ± 10	98 ± 15	94 ± 10	119 ± 7
Weight	82 ± 11	97 ± 13	95 ± 11	112 ± 15	104 ± 14	97 ± 12	102 ± 14	97 ± 9	100 ± 15	89 ± 13	116 ± 11
Fat%	98 ± 12	99 ± 15	99 ± 15	99 ± 15	102 ± 14	106 ± 14	97 ± 19	97 ± 14	103 ± 7	90 ± 16	101 ± 12
BMI	94 ± 11	100 ± 14	95 ± 15	101 ± 15	102 ± 15	108 ± 14	97 ± 14	98 ± 17	102 ± 9	89 ± 14	104 ± 13
Handgrip	86 ± 14	96 ± 15	100 ± 14	105 ± 15	106 ± 17	101 ± 14	100 ± 14	97 ± 12	103 ± 13	89 ± 11	109 ± 13
Curl-ups	109 ± 20	94 ± 14	102 ± 13	101 ± 16	104 ± 18	112 ± 10	103 ± 11	99 ± 12	106 ± 14	92 ± 16	115 ± 12
Knee Push-ups	113 ± 14	100 ± 14	105 ± 16	95 ± 14	98 ± 13	108 ± 12	90 ± 12	104 ± 13	113 ± 13	95 ± 13	91 ± 10
Standing broad jump	107 ± 11	95 ± 12	103 ± 14	103 ± 14	100 ± 12	110 ± 10	108 ± 11	103 ± 20	101 ± 15	91 ± 11	121 ± 12
Shoulder rotation	128 ± 12	99 ± 12	104 ± 8	93 ± 14	94 ± 15	100 ± 11	109 ± 13	105 ± 15	101 ± 12	104 ± 14	100 ± 15
Sit and reach	124 ± 6	96 ± 13	109 ± 11	93 ± 16	99 ± 14	101 ± 18	105 ± 15	107 ± 11	100 ± 12	101 ± 19	104 ± 15
Shuttle run 10x5m	100 ± 12	100 ± 13	110 ± 13	98 ± 15	100 ± 12	115 ± 14	104 ± 12	100 ± 12	107 ± 10	88 ± 10	108 ± 15
Endurance shuttle run	77 ± 15	103 ± 11	105 ± 13	101 ± 13	103 ± 12	97 ± 10	91 ± 1	107 ± 14	111 ± 8	113 ± 10	104 ± 8
KTK balance beam	112 ± 8	100 ± 14	100 ± 16	94 ± 18	103 ± 14	103 ± 14	102 ± 12	96 ± 17	102 ± 12	103 ± 14	96 ± 16
KTK jumping sideways	107 ± 12	102 ± 13	109 ± 11	98 ± 17	98 ± 17	98 ± 17	107 ± 13	104 ± 12	108 ± 15	93 ± 13	94 ± 13
KTK moving sideways	105 ± 17	98 ± 13	103 ± 12	99 ± 18	97 ± 14	97 ± 14	112 ± 21	106 ± 18	104 ± 16	107 ± 17	97 ± 15
Dribbling	91 ± 17	104 ± 7	100 ± 8	112 ± 4	109 ± 6	109 ± 6	86 ± 13	104 ± 5	106 ± 8	98 ± 14	103 ± 7

The standing broad jump of 1.76m performed by an 11-year-old boy when compared to his peers at school is a good performance. The average for his age group is 1.51m and the standard deviation is 0.21m. The result of the calculated Z-score = + 1.19 and this Z-score is equal to a PQ score of 121. The demands for triathlon (PQ standing broad jump = 91 ± 11) and judo (PQ standing broad jump = 110 ± 10) are different. Recalculated to raw scores the score for standing broad jump for triathletes are less demanding (137 cm ± 15 cm) than the demands for the same age group for judo (166 cm ± 14 cm). The interpretation of a 1.76m standing broad jump for an 11-year-old boy measured in the context of the primary school PE lesson (PQ = 121) differs from the interpretation of the same result measured by the triathlon federation (PQ = 139) or the judo federation (PQ = 111).

The quotient score strategy was implemented in the "Flemish elite sport schools" (n= 1424). Adolescents practicing their sport at the highest level in Flanders were measured with the same test battery used in the primary schools. All athletes performed the different test, even if the characteristics were not useful in their sport. Gymnasts performed the dribble test and basketball players were asked to perform the KTK balance beam test. The collected data from this preliminary study provided some interesting results. The confirmation that volleyball players are tall (AQ for stature = 119 ± 7), that judoïsts have the best scores for strength (PQ for curl-ups = 112 ± 10 and knee push-ups = 108 ± 12) is quite clear and reconfirm previous studies (Bayios, et al., 2006; Krstulovic, et al., 2006; Franchini, E., et al., 2007; Gabbett and Georgieff, 2007; Lidor and Ziv, 2010; Kurt, C., et al., 2010). When using this concept it is important to realize that the system is a linear approach based on average scores. In fact a player can very well compensate for specific shortcomings in one of the characterisitcs by being extremely well in another characteristic that is crucial for successful performance (Buekers et al., 2014). The global information however exemplifies the differences between sports. However Bartmus et al. (1987) suggested that the reliability of the prediction is reversed with the period prior to the time the assessment is provided. This indicates that the development lines run different for each talent characterisitc and that they may also differ individually depending on the individual training level and maturity.

Descriptive statistics with measurements of central tendency and measures of dispersion can provide insights when comparing athletes. For the comparison between groups and the prediction of future performance more advanced statistical techniques i.e. regression analysis, discriminant analysis and artificial neural networks are required.

Cross sport comparisons

The raw data obtained in the study implemented in the "Flemish elite sport schools" (n= 1424) were normalized for gender and age into quotient scores. First, all participants were filtered by gender and age. Second, the quotient scores were calculated for each group separately. Third, All the quotient scores were collected from all the different age groups. Finally, all quotient scores were filtered per sport. This approach is straightforward and can provoke discussion, although in the preliminary phase of this project it demonstrated the importance of the generic performance factors in different sports (Figure 14).

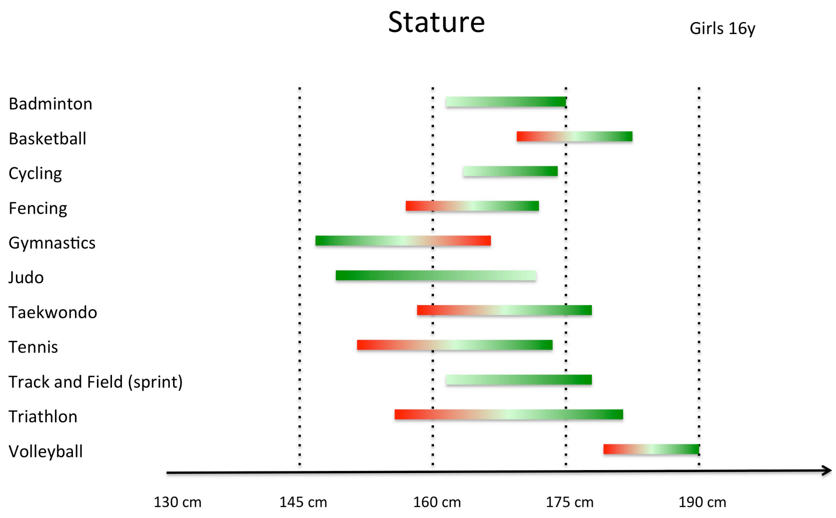


Figure 14: Cross sport comparison for stature in 16-year-old girls (Flanders Elite Sports Schools)

Note: The bar with the colour transition from a green (good) over white (average) to red (inferior) represents the population, which is within one standard deviation of the mean. The more a gymnast is taller, the more he moves towards the red side. The bar is entirely green for badminton; cycling; judo and athletics since stature is less restrictive for these sports. A small stature for gymnastics is required (<150cm) and therefore the green side will be on the opposite side of the green side for volleyball players.

Tackling the maturity problem

The results from the Flemish Sports Compass assessed in the Flemish elite sport schools (2008-2010) showed some remarkable differences between late, normal and early mature soccer players. Figure 15 demonstrates that the stature of the early mature boys corresponds to the next age group. In Figure 16 the same principle can be observed with the stature of the late mature boys that correspond to the previous age group.

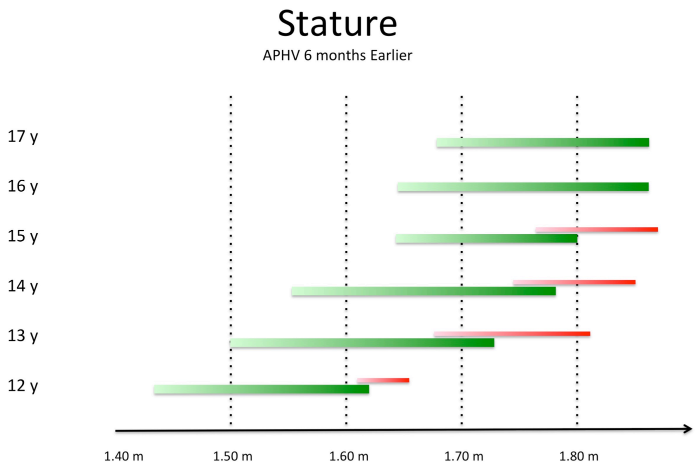


Figure 15: Differences between early mature and normal developing soccer players for stature.

Note: The green bar represents the normal developing soccer players, which are within one standard deviation of the mean. The red bar represents the early mature soccer players, which are within one standard deviation of the mean.

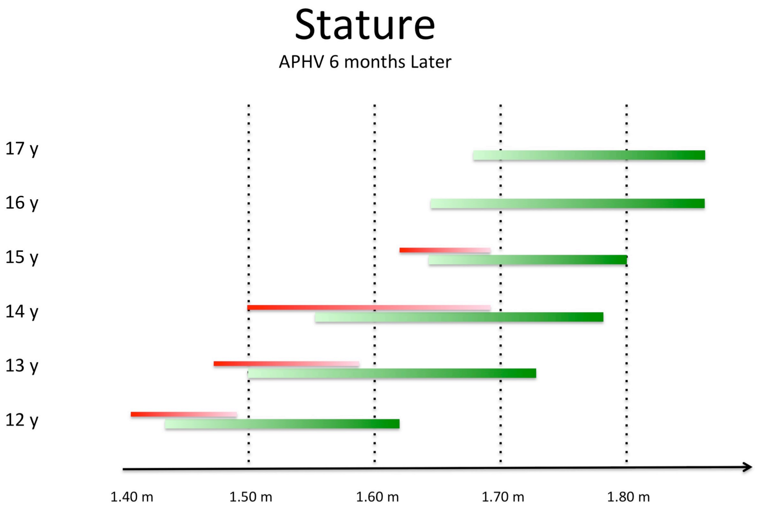


Figure 16: Differences between late mature and normal developing soccer players for stature.

Note: The green bar represents the normal developing soccer players, which are within one standard deviation of the mean. The red bar represents the late mature soccer players, which are within one standard deviation of the mean.

It was observed that the early mature soccer players from the Flemish elite sport schools develop their sprinting abilities later, although at the age of 17 the late mature finally come at the same level of the normal developing players. Selecting for speed in 12 to 14 year old boys involves risks of missing high potentials. Especcially, when the population consists of early mature survivors of previous selections (Figure 17).

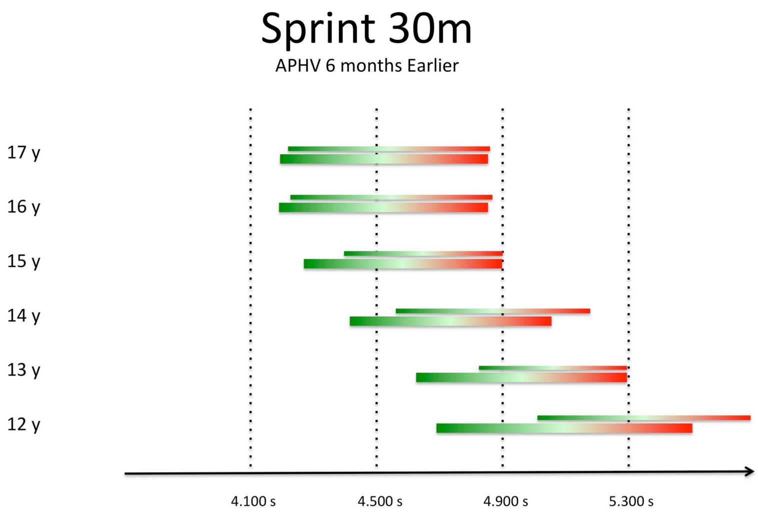


Figure 17: Differences between late mature and normal developing soccer players for speed (30m Sprint).

Note: The lower bar with the colour transition from a green (good) over white (average) to red (inferior) represents the normal developing soccer players, which are within one standard deviation of the mean. The upper bar represents the early mature soccer players, which are within one standard deviation of the mean.

A same phenomenon was observed in strength with the development of the late mature soccer players. Special attention is needed for the split that occurs between the late mature and normal developing players. Late mature boys have a disadvantage when selecting for strength (Figure 18).

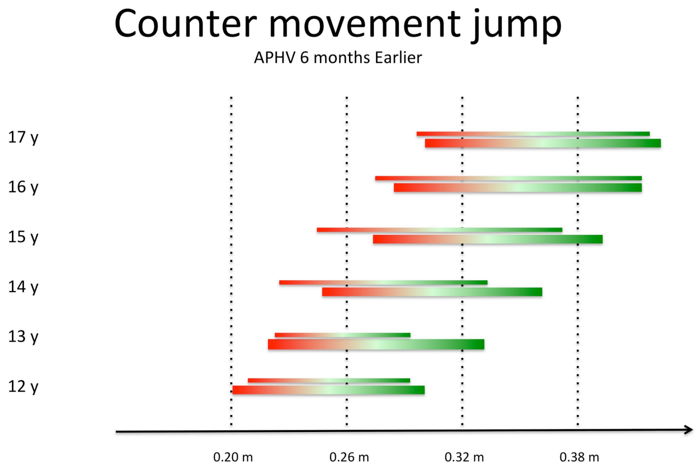


Figure 18: Differences between late mature and normal developing soccer players for strength (CMJ).

Note: The bar with the colour transition from a green (good) over white (average) to red (inferior) represents the population, which is within one standard deviation of the mean. The lower bar represents the normal developing soccer players, which are within one standard deviation of the mean. The upper bar represents the early mature soccer players.

The disadvantages for late mature boys for strength and speed cannot be generalized for motor coordination or for soccer specific motor coordination tests (Figure 19 and Figure 20).

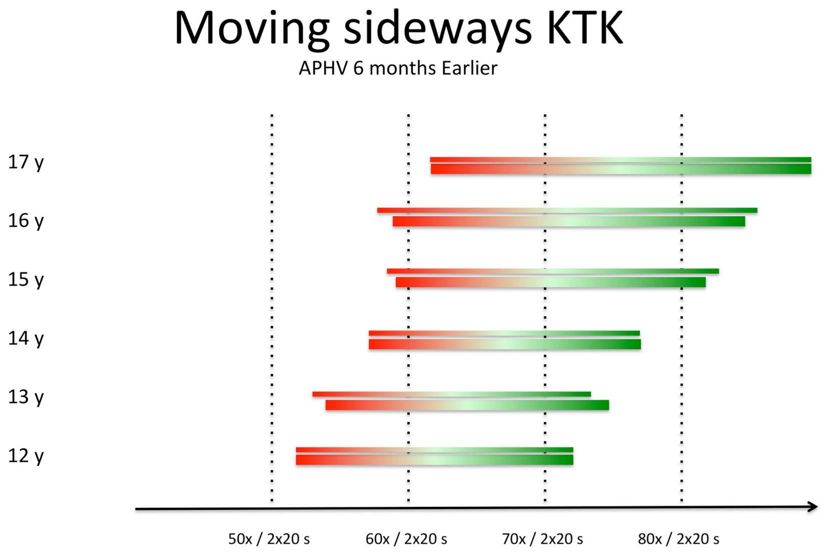


Figure 19: Differences between late mature and normal developing soccer players for motor coordination

Note: The bar with the colour transition from a green (good) over white (average) to red (inferior) represents the population, which is within one standard deviation of the mean. The lower bar represents the normal developing soccer players, which are within one standard deviation of the mean. The upper bar represents the early mature soccer players.

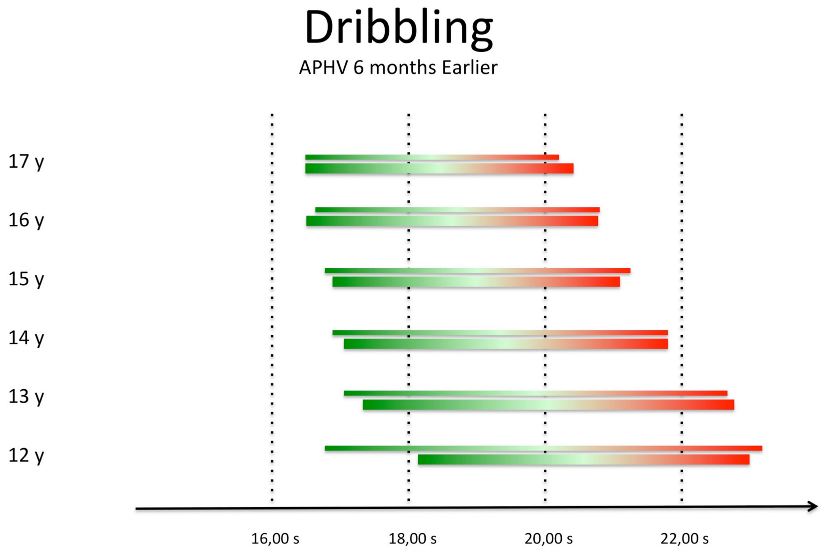


Figure 20: Differences between late mature and normal developing soccer players for sport specific coordination

Note: The bar with the colour transition from a green (good) over white (average) to red (inferior) represents the population, which is within one standard deviation of the mean. The lower bar represents the normal developing soccer players, which are within one standard deviation of the mean. The upper bar represents the early mature soccer players.

Based on this preliminary findings from the assessments in the Flemish elite sport schools, Vandendriessche et al. (2012) reported the morphology (height, weight, body fat, body mass index), fitness (strength, speed, agility, flexibility), and soccer-specific (dribbling) and non-specific motor coordination skills (Körper KoordinationsTest für Kinder; KTK) of 78 Belgian “international” youth soccer players aged 15-16 years with varying biological maturity status. The more mature players (U16 and U17) possessed higher morphological measures and outperformed their later maturing peers (U16 Futures and U17 Futures) on almost all fitness tests. However, soccer-specific and non-specific motor coordination tests did not distinguish the more mature players from the later maturing players in both age groups. When adjusted for the confounder (age at peak height velocity), multivariate analysis of covariance revealed that several morphology- and fitness-related parameters did not differ between selection groups, again in both age groups. These findings indicate that biological maturation affects morphology and fitness more so than motor coordination skills. In conclusion, to prevent the dropout of promising late maturing players, Vandendriessche and colleagues (2012) suggested avoiding one-dimensional approaches and to include measures of biological maturity status as well as maturity independent performance tests during the talent identification and selection process.

PHASE 6: VALIDITY OF THE DIFFERENT PROFILES

The gifted athletes are the ‘better movers’

The results of girls and boys from the elite sports schools can be compared to their peers for some of the generic characteristics. According to Gagné (2004) 10% of the population can be considered as gifted in the sensorimotor domain. This statement was examined with the sample of the Flemish elite sports schools. It was demonstrated that more than 50% of the boys (in all age groups) from the elite population scored above the P90 of the normal developing boys for shuttle run, standing broad jump, endurance shuttle run and jumping sideways. Table 6 demonstrates that 99% of the athletes from the Flemish elite sports schools score better than P50 for the shuttle run test and even 94% scored higher than P90 of the normal population. This example demonstrates the narrow border between giftedness and talent. 94% of the trained athletes of the Flemish elite sports schools can be considered as gifted for speed and agility, although 10% (instead of 94%) can be defined as talented according to the definition of Gagné (2004).

Table 6: Comparison between boys from elite sports schools and their peers for performance characteristics.

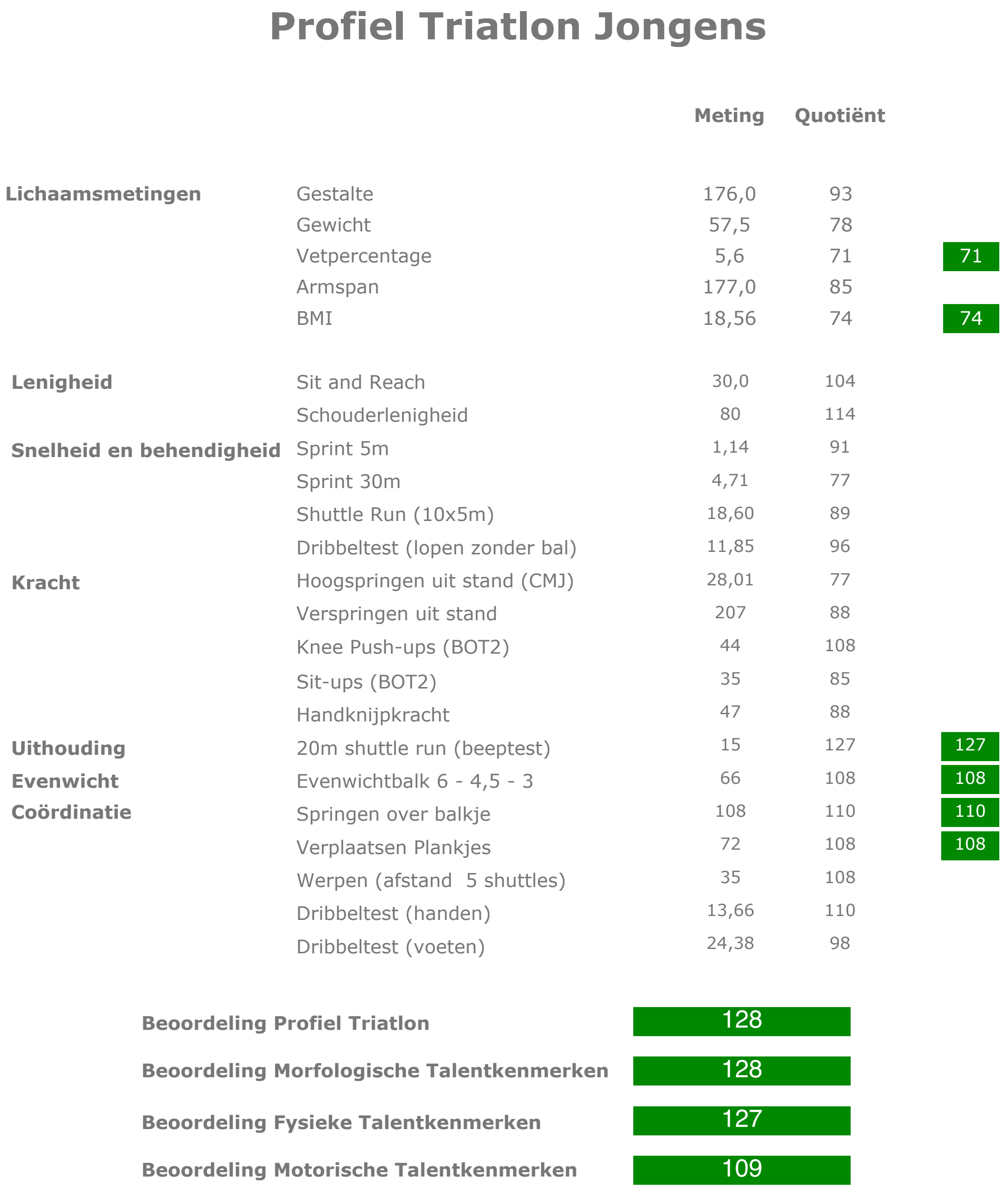
Measurement	Reference	Boys (12y)		Boys (13y)		Boys (14y)		Boys (15y)		Boys (16y)		Boys (17y)	
		P50	P90	P50	P90	P50	P90	P50	P90	P50	P90	P50	P90
Sit and reach	EUROFIT	77%	39%	69%	27%	77%	34%	84%	34%	66%	21%	76%	35%
Shuttle run	EUROFIT	99%	94%	98%	81%	100%	91%	100%	86%	99%	91%	99%	93%
Standing broad jump	EUROFIT	99%	54%	80%	29%	87%	39%	86%	38%	88%	48%	80%	33%
Endurance shuttle run	EUROFIT	100%	78%	96%	63%	99%	73%	98%	67%	94%	65%	99%	70%
KTK balance beam	KTK	57%	23%	54%	11%								
KTK jumping sideways	KTK	96%	81%	99%	76%								
KTK moving sideways	KTK	83%	47%	93%	44%								

More than 50% of the 12-year-old girls (in all age groups) from the elite population scored above the P90 of the normal developing girls for shuttle run, endurance shuttle run and jumping sideways. The same applies from the age of 13 for the standing broad jump.

Table 7: Comparison between girls from elite sports schools and their peers for performance characteristics.

Measurement	Reference	Girls (12y)		Girls (13y)		Girls(14y)		Girls (15y)		Girls (16y)		Girls (17y)	
		P50	P90	P50	P90	P50	P90	P50	P90	P50	P90	P50	P90
Sit and reach	EUROFIT	80%	24%	65%	23%	88%	31%	79%	37%	76%	36%	84%	34%
Shuttle run	EUROFIT	100%	98%	100%	97%	100%	96%	100%	100%	100%	96%	100%	100%
Standing broad jump	EUROFIT	88%	44%	97%	68%	99%	72%	100%	84%	100%	64%	100%	74%
Endurance shuttle run	EUROFIT	100%	91%	100%	94%	100%	98%	100%	92%	100%	88%	100%	10%
KTK balance beam	KTK	63%	23%	59%	19%								
KTK jumping sideways	KTK	96%	81%	88%	24%								
KTK moving sideways	KTK	82%	47%	90%	60%								

A Filemaker tool was applied to highlight that gifted athletes show sport specific characteristics. The generic testbattery provides different outputs for each sport specific test profile. Figure 21 and Figure 22 demonstrate how the specific talent characteristics are highlighted in the output form from the Flemish Sports Compass that was conducted in the Flemish elite sports schools. The relevant talent characteristics are accentuated in green (good) or red (poor). Total scores for all sport specific characteristics resulted in a sport specific profile and in addition a score for anthropometry, physical performance and motor coordination was calculated for each individual. In the preliminary phase no weighting factors were applied for the specific characteristics to calculate the sum scores.

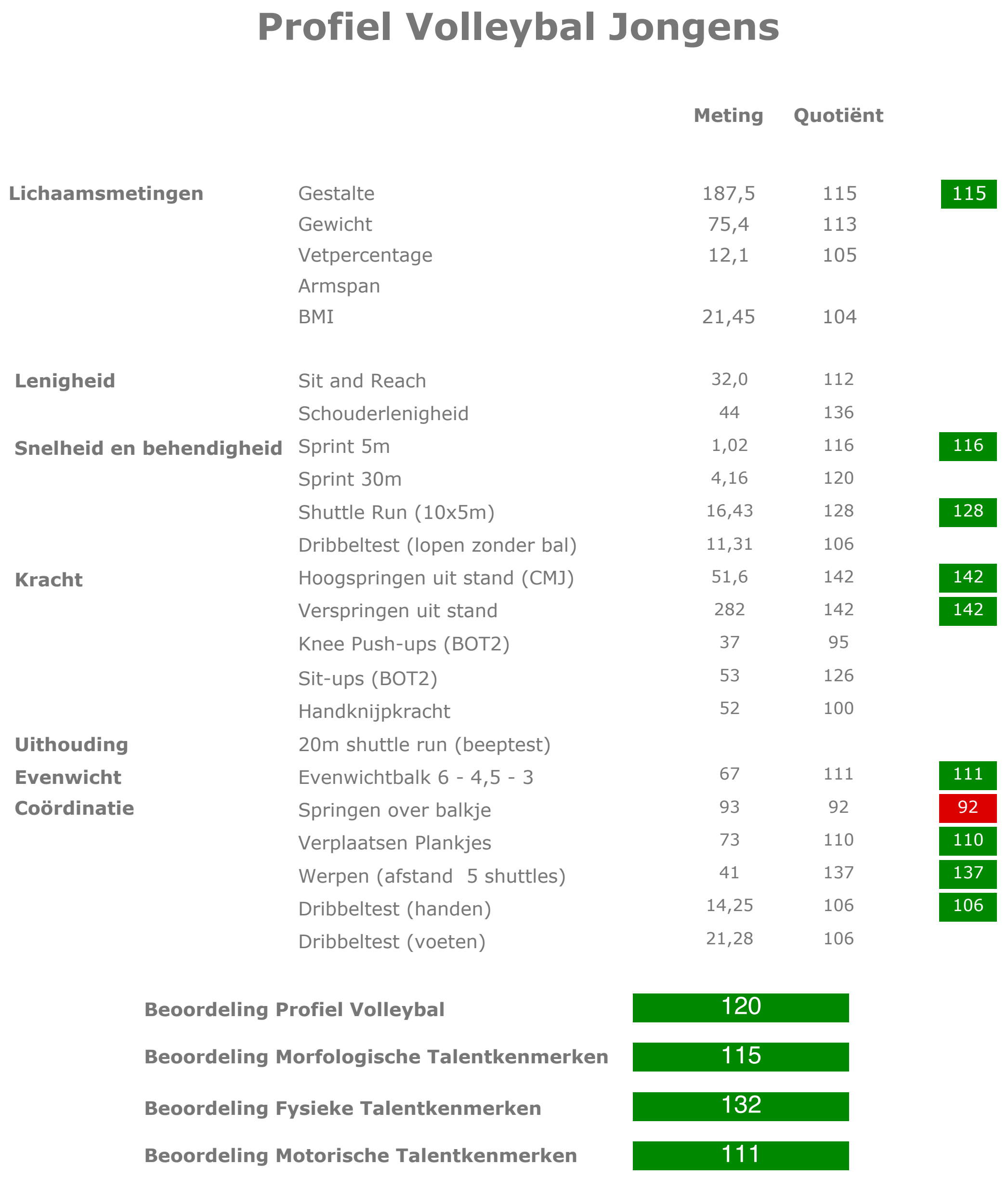


Profiel Triatlon Jongens

		Meting	Quotiënt	
Lichaamsmetingen	Gestalte	176,0	93	
	Gewicht	57,5	78	
	Vetpercentage	5,6	71	71
	Armspan	177,0	85	
	BMI	18,56	74	74
Lenigheid	Sit and Reach	30,0	104	
	Schouderlenigheid	80	114	
Snelheid en behendigheid	Sprint 5m	1,14	91	
	Sprint 30m	4,71	77	
	Shuttle Run (10x5m)	18,60	89	
	Dribbeltest (lopen zonder bal)	11,85	96	
Kracht	Hoogspringen uit stand (CMJ)	28,01	77	
	Verspringen uit stand	207	88	
	Knee Push-ups (BOT2)	44	108	
	Sit-ups (BOT2)	35	85	
	Handknijpkracht	47	88	
Uithouding	20m shuttle run (beeptest)	15	127	127
Evenwicht	Evenwichtbalk 6 - 4,5 - 3	66	108	108
Coördinatie	Springen over balkje	108	110	110
	Verplaatsen Plankjes	72	108	108
	Werpen (afstand 5 shuttles)	35	108	
	Dribbeltest (handen)	13,66	110	
	Dribbeltest (voeten)	24,38	98	

Beoordeling Profiel Triatlon	128
Beoordeling Morfologische Talentkenmerken	128
Beoordeling Fysieke Talentkenmerken	127
Beoordeling Motorische Talentkenmerken	109

Figure 21: Sport specific output from the generic test battery triathlon (Flemish elite sport schools)



Profiel Volleybal Jongens

		Meting	Quotiënt	
Lichaamsmetingen	Gestalte	187,5	115	🟩 115
	Gewicht	75,4	113	
	Vetpercentage	12,1	105	
	Armspan			
	BMI	21,45	104	
Lenigheid	Sit and Reach	32,0	112	
	Schouderlenigheid	44	136	
Snelheid en behendigheid	Sprint 5m	1,02	116	🟩 116
	Sprint 30m	4,16	120	
	Shuttle Run (10x5m)	16,43	128	🟩 128
	Dribbeltest (lopen zonder bal)	11,31	106	
Kracht	Hoogspringen uit stand (CMJ)	51,6	142	🟩 142
	Verspringen uit stand	282	142	🟩 142
	Knee Push-ups (BOT2)	37	95	
	Sit-ups (BOT2)	53	126	
	Handknijpkracht	52	100	
Uithouding	20m shuttle run (beeptest)			
Evenwicht	Evenwichtbalk 6 - 4,5 - 3	67	111	🟩 111
Coördinatie	Springen over balkje	93	92	🟥 92
	Verplaatsen Plankjes	73	110	🟩 110
	Werpen (afstand 5 shuttles)	41	137	🟩 137
	Dribbeltest (handen)	14,25	106	🟩 106
	Dribbeltest (voeten)	21,28	106	

Beoordeling Profiel Volleybal	🟩 120
Beoordeling Morfologische Talentkenmerken	🟩 115
Beoordeling Fysieke Talentkenmerken	🟩 132
Beoordeling Motorische Talentkenmerken	🟩 111

Figure 22: Sport specific output from the generic test battery volleyball (Flemish elite sport schools)

The different techniques described in this chapter are the precursors of the original research in part two of this dissertation. The transition from descriptive statistical methods to linear and non-linear predictive methods is indispensable in the current talent search.

References

1. Ahnert J, Schneider W, K B. Developmental changes and individual stability of motor abilities from the preschool period to young adulthood. In: Schneider W, Bullock MR eds, Human development from early childhood to early adulthood: Evidence from the Munich Longitudinal Study on the Genesis of individual Competencies (LOGIC). Mahwah: NJ: Erlbaum; 2009: 35-62
2. Allen, G. D. (1991). "Physiological-Characteristics of Elite Australian Table-Tennis Athletes and Their Responses to High-Level Competition." Journal of Human Movement Studies20(3): 133-147.
3. Almansba, R., S. Sterkowicz, R. Belkacem, K. Sterkowicz-Przybycien and D. Mahdad (2010). "Anthropometrical and physiological profiles of the Algerian Olympic judoists." Archives of Budo 6(4): 185-193.
4. Amusa, L. O., A. L. Toriola, H. S. Dhaliwal and M. M. Mokgwathi (2001). "Anthropometric profile of Botswana junior national badminton players." Journal of Human Movement Studies 40(2): 115-128.
5. Aouadi, R., M. C. Jlid, R. Khalifa, S. Hermassi, M. S. Chelly, R. Van den Tillaar and T. Gabbett (2012). "Association of anthropometric qualities with vertical jump performance in elite male volleyball players." Journal of Sports Medicine and Physical Fitness 52(1): 11-17.
6. Bajin, B. (1987). Talent identification program for Canadian female gymnasts. World identification Systems for gymnastic talent. B. Petiot, J. H. Salmela and T. B. Hoshizaki. Montreal, Sport Psyche editions: 34-44.
7. Bala, G. and P. Drid (2010). "Anthropometric and Motor Features of Young Judoists in Vojvodina." Collegium Antropologicum 34(4): 1347-1353.
8. Bale, P. (1991). "Anthropometric, Body-Composition and Performance Variables of Young Elite Female Basketball Players." Journal of Sports Medicine and Physical Fitness 31(2): 173-177.
9. Bartmus U, Neumann E, de Marees H (1987). The talent problem in sports, International Journal of Sports Medicine 8 (6), pp 415-416
10. Bayios IA, Bergeles NK, Apostolidis NG, Noutsos KS, and Koskolou MD. Anthropometric, body composition and somatotype differences of Greek elite female basketball, volleyball and handball players. J Sport Med Phys Fit 46: 271-280, 2006.
11. Ben Abdelkrim, N., C. Castagna, I. Jabri, T. Battikh, S. El Fazaa and J. El Ati (2010). "Activity Profile and Physiological Requirements of Junior Elite Basketball Players in Relation to Aerobic-Anaerobic Fitness." Journal of Strength and Conditioning Research 24(9): 2330-2342.
12. Bencke, J., R. Damsgaard, A. Saekmose, P. Jorgensen, K. Jorgensen and K. Klausen (2002). "Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming." Scandinavian Journal of Medicine & Science in Sports 12(3): 171-178.
13. Boguszewska, K., D. Boguszewski and K. Busko (2010). "Special Judo Fitness Test and biomechanics measurements as a way to control of physical fitness in young judoists." Archives of Budo 6(4): 205-209.
14. Booysen (2008). Designing a protocol and comparative norms for the identification and selection of talent among elite age-group rugby players in South Africa (dissertation). University of Pretoria.
15. Borras, X., X. Balius, F. Drobnic and P. Galilea (2011). "Vertical Jump Assessment on Volleyball: A Follow-up of Three Seasons of a High-Level Volleyball Team." Journal of Strength and Conditioning Research 25(6): 1686-1694.
16. Bottoni, A., A. Gianfeliici, R. Tamburri and M. Faina (2011). "Talent selection criteria for olympic distance triathlon." Journal of human sport and exercise 6(2): i-xii.
17. Breitbach S, Tug S, Simon P. (2014).” Conventional and genetic talent identification in sports: will recent developments trace talent? Sports Medicine, 2014, Nov 44 (11), 1489-1503
18. Bruininks RH, Bruininks BD (2006) BOT-2 Bruininks-Oseretsky Test of Motor Proficiency. 2nd ed. Minneapolis MN) AGS Publishing
19. Buekers, M., Borry, P., & Rowe, P. (2014). Talent in sports. Some reflections about the search for future champions. *Movement & Sport Sciences-Science & Motricité*.
20. Campos, F. A. D., L. B. Daros, V. Mastrascusa, A. C. Dourado and L. C. R. Stanganelli (2009). " Anthropometric profile and motor performance of junior badminton players." Brazilian Journal of Biomotricity 3(2): 146-151.
21. Carling, C., F. le Gall, T. Reilly and A. M. Williams (2009). "Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players?" Scandinavian Journal of Medicine & Science in Sports 19(1): 3-9.
22. Chin, M. K., A. S. K. Wong, R. C. H. So, O. T. Siu, K. Steininger and D. T. L. Lo (1995). "Sport Specific Fitness Testing of Elite Badminton Players." British Journal of Sports Medicine 29(3): 153-157.

23. De Albuquerque, P. A. and P. T. V. Farinatti (2007). "Development and validation of a new system for talent selection in female artitic gymnastics; the PDGO battery." revista Brasileira de Medicina do Esporte 13(3): 139e-145e.
24. Diaz, V., A. G. Zapico, A. B. Peinado, A. Alvarez, P. J. Benito and F. J. Calderon (2009). "Physiological profile of elite triathletes: a comparison between young and professional competitiors." Journal of human sport and exercise 4(3): 237.
25. Drinkwater, E. J., D. B. Pyne and M. J. McKenna (2008). "Design and interpretation of anthropometric and fitness testing of basketball players." Sports Medicine 38(7): 565-578.
26. Duncan, M. J., L. Woodfield and Y. al-Nakeeb (2006). "Anthropometric and physiological characteristics of junior elite volleyball players." British Journal of Sports Medicine 40(7): 649-651.
27. Elferink-Gemser, M. T., B. C. H. Huijgen, M. Coelho-E-Silva, K. A. P. M. Lemmink and C. Visscher (2012). "The changing characteristics of talented soccer players - a decade of work in Groningen." Journal of Sports Sciences 30(15): 1581-1591.
28. Faber, I., F. Oosterveld and R. Nijhuis-Van der Sanden (2011). A first step to an evidence-based talent identification program in the Netherlands: a research proposal. 12th ITTF Sport Science Congress. Rotterdam, The Netherlands.
29. Falk, B., Lidor, R., Lander, Y., & Lang, B. (2004). Talent identification and early development of elite water-polo players: a 2-year follow-up study. *Journal of Sports Sciences*, *22*(4), 347-355.
30. Faude, O., T. Meyer, F. Rosenberger, M. Fries, G. Huber and W. Kindermann (2007). "Physiological characteristics of badminton match play." European Journal of Applied Physiology 100(4): 479-485.
31. Franchini, E., A. V. Nunes, J. M. Moraes and F. B. Del Vecchio (2007). "Physical Fitness and Anthropometrical Profile of the brazilian Male Judo Team." Journal of Physiological Anthropology 26: 59-67.
32. Gabbett, T., B. Georgieff and N. Domrow (2007). "The use of physiological, anthropometric, and skill data to predict selection in a talent-identified junior volleyball squad." Journal of Sports Sciences 25(12): 1337-1344.
33. Gabbett, T., Kelly, J., Ralph, S., & Driscoll, D. (2009). Physiological and anthropometric characteristics of junior elite and sub-elite rugby league players, with special reference to starters and non-starters. *Journal of Science and Medicine in Sport*, *12*(1), 215-222.
34. Gagné (2004) Transforming gifts into talents: the DMGT as a developmental theory. High Ability Studies, 2004. 15(2): p. 119-147.
35. Galal, E. H., I. Zapartidis and H. Ibrahim (2011). "A Comparative Study between Talented Young Greek and German Handball Players in Some Physical and Anthropometric Characteristics." Biology of Sport 28(4): 245-248.
36. Gil, S. M., J. Gil, F. Ruiz, A. Irazusta and J. Irazusta (2007). "Physiological and anthropometric characteristics of young soccer players according to their playing position: Relevance for the selection process." Journal of Strength and Conditioning Research 21(2): 438-445.
37. Gomes, F., F. Amaral, A. Ventura and J. Agular. (2002). "Table tennis specific test battery." from http://www.ittf.com.
38. Gonaus, C. and E. Muller (2012). "Using physiological data to predict future career progression in 14-to 17-year-old Austrian soccer academy players." Journal of Sports Sciences 30(15): 1673-1682.
39. Grabiner, M. D. and R. McKelvain (1987). Implementation of a profiling: prediction test battery in the screening of elite men gymnasts. World identification systems for gymnastics talent. B. Petiot, J. H. Salmela and T. B. Hoshizaki. Montreal, Sport Psyche editions: 121-125.
40. Hauke. (2005). "Training des Leistungsfaktors Kondition Ausdauerfahigkeiten, B-trainer Ausbildung."
41. Hoare, D. G. (2000). "Predicting success in junior elite basketball players: the contribution of anthropometric and physiological attributes." Journal of Science and Medicine in Sport 3: 391-405.
42. Howe, M. J., Davidson, J. W., & Sloboda, J. A. (1998). Innate talents: Reality or myth? *Behavioral and brain sciences*, *21*(03), 399-407.
43. Hughes, M. G., M. Andrew and R. Ramsay (2003). "A sport-specific endurance performance test for elite badminton players." Journal of Sports Sciences 21(4): 277-278.
44. Jaric, S., D. Ugarkovic and M. Kukolj (2001). "Anthropometric, strength, power and flexibility variables in elite male athletes: Basketball, handball, soccer and volleyball players." Journal of Human Movement Studies 40(6): 453-464.
45. Karpowicz, K. (2006). "Interrelation of selected factors determining the effectiveness of training in young basketball players." Human Movement Science 7: 130-146.
46. Kavouras, S. A. (1993). Growth, Maturation and Performance Evaluation of Elite Age Group Swimmers. 1992 United States Swimming Camp Report.
47. Kiphard EJ, Schilling F. (1974) Körperkoordinationstest für Kinder, Weinheim: Beltz Test Gmbh.
48. Kiphard EJ, Schilling F. Körperkoordinationstest für Kinder 2. Überarbeitete und ergänzte Auflage. Weinheim: Beltz: Test GmbH. 2007

49. Knechtle, B., P. Knechtle, J. L. Andonie and G. Kohler (2007). "Influence of anthropometry on race performance in extreme endurance triathletes: World Challenge Deca Iron Triathlon 2006." Br J Sports Med 41(10): 644-648; discussion 648.
50. Kondric, M., D. Sekulic and G. F. Mandic (2010). "Substance Use and Misuse Among Slovenian Table Tennis Players." Substance Use & Misuse 45(4): 543-553.
51. Krawczyk, B., M. Sklad and A. Jackiewicz (1997). "Heath-Carter somatotypes of athletes representing various sports." Biology of Sport 14(4): 305-310.
52. Krstulovic, S., D. Sekulic and H. Sertic (2005). "Anthropological determinants of success in young judoists." Collegium Antropologicum 29(2): 697-703.
53. Krstulovic, S., F. Zuvela, and R. Katic, Biomotor systems in elite junior judoists. Collegium Antropologicum, 2006. 30(4): p. 845-851.
54. Kurt, C., I. Kobas, S. Ayas, M. D. Dindar and I. K. Omurlu (2010). "The Body composition and some conditional features of women judoists of the Turkish national team." Facta Universitatis, Physical Education ansd Sport 8(2): 133-139.
55. Lenoir M., Pion J (2011) Het Vlaams Sport Kompas, eindrapport van het project Talentdetectie en –identificatie (2007-2011), Universiteit Gent.
56. Leone, M., Lariviere, G., & Comtois, A. S. (2002). Discriminant analysis of anthropometric and biomotor variables among elite adolescent female athletes in four sports. Journal of sports sciences, 20(6), 443-449.
57. Lidor, R., A. Falk, M. Arnon, Y. Cohen, G. Segal and Y. Lander (2005). "Measurement of talent in team handball: The questionable use of motor and physical tests." Journal of Strength and Conditioning Research 19(2): 318-325.
58. Lidor R and Ziv G. Physical and Physiological Attributes of Female Volleyball Players-a Review. J Strength Cond Res 24: 1963-1973, 2010.
59. Little, N. G. (1991). "Physical Performance Attributes of Junior and Senior Women, Juvenile, Junior, and Senior Men Judokas." Journal of Sports Medicine and Physical Fitness 31(4): 510-520.
60. Mahadi, A. and R. Sing. (2007). "talent identification in Malaysia." from http://www.nie.edu.sg.
61. Majumdar, P., G. L. Khanna, V. Malik, S. Sachdeva, M. Arif and M. Mandal (1997). "Physiological analysis to quantify training load in badminton." British Journal of Sports Medicine 31(4): 342-345.
62. Manrique, D. C. and J. J. Gonzalez-Badillo (2003). "Analysis of the characteristics of competitive badminton." British Journal of Sports Medicine 37(1): 62-66.
63. Matsudo, V.K.R., Rivet, R.E., Pereira, M.H.N., (1987), Standard score assessment on physique and performance of Brazilian athletes in a six tiered competitive sports model, Journal of Sports Sciences, 5, pp 49-53
64. Matsudo VKR. (1996), Prediction of future athletic excellence. In: Bar-Or O, editor. The child and adolescent athlete. Oxford: Blackwell Scientific Publications; p. 92—109. Matthys, S. P. J., R. Vaeyens, M. J. Coelho-e-Silva, M. Lenoir and R. Philippaerts (2012). "The Contribution of Growth and Maturation in the Functional Capacity and Skill Performance of Male Adolescent Handball Players." International Journal of Sports Medicine 33(7): 543-549.
65. Matthys, S. P. J., R. Vaeyens, J. Vandendriessche, B. Vandorpe, J. Pion, A. J. Coutts, M. Lenoir and R. M. Philippaerts (2011). "A multidisciplinary identification model for youth handball." European Journal of Sport Science 11(5): 355-363.
66. Mcclay, I. S., J. R. Robinson, T. P. Andriacchi, E. C. Frederick, T. Gross, P. Martin, G. Valiant, K. R. Williams and P. R. Cavanagh (1994). "A Profile of Ground Reaction Forces in Professional Basketball." Journal of Applied Biomechanics 10(3): 222-236.
67. Meyer, T., B. Coen, A. Urhausen, P. Wilking, S. Honorio and W. Kindermann (2005). "Konditionelles Profil jugendlicher Fussballspieler." Deutsche Zeitschrift fuer Sportmedizin 56(1): 20-25.
68. Mirkov, D. M., M. Kukolj, D. Ugarkovic, V. J. Koprivica and S. Jaric (2010). "Development of Anthropometric and Physical Performance Profiles of Young Elite Male Soccer Players: A Longitudinal Study." Journal of Strength and Conditioning Research 24(10): 2677-2682.
69. Mohamed, H., R. Vaeyens, S. Matthys, M. Multael, J. Lefevre, M. Lenoir and R. Philippaerts (2009). "Anthropometric and performance measures for the development of a talent detection and identification model in youth handball." Journal of Sports Sciences 27(3): 257-266.
70. Monteiro (2001) handball
71. Nystrom (1990) fencing
72. Ooi, C. H., A. Tan, A. Ahmad, K. W. Kwong, R. Sompong, K. A. M. Ghazali, S. L. Liew, W. J. Chai and M. W. Thompson (2009). "Physiological characteristics of elite and sub-elite badminton players." Journal of Sports Sciences 27(14): 1591-1599.

73. Petiot, B. (1987). Differences anthropométriques entre les gymnastes masculins de spécialités differentes. World identification systems for gymnastic talent. B. Petiot, J. H. Salmela and T. B. Hoshizaki. Montreal, Sport psyche editions: 77-93.
74. Reilly, T., A. M. Williams, A. Nevill and A. Franks (2000). "A multidisciplinary approach to talent identification in soccer." Journal of Sports Sciences 18(9): 695-702.
75. Rimm (1984)
76. Sattler, T., D. Sekulic, V. Hadzic, O. Uljevic and E. Dervisevic (2012). "Vertical Jumping Tests in Volleyball: Reliability, Validity, and Playing-Position Specifics." Journal of Strength and Conditioning Research 26(6): 1532-1538.
77. Schoemaker, M. M., Smits-Engelsman, B. C. M., & Jongmans, M. J. (2003). Psychometric properties of the Movement ABC Checklist as a screening instrument for children with Developmental Coordination Disorder. *Br J Educ Psychol*, *73*, 425-41.
78. Sertic, H., I. Segedi and D. Milanovic (2006). "Anthropological and fitness status of Croatian judoists." Archives of Budo 2: 24-27.
79. Sheppard, J. M., J. B. Cronin, T. J. Gabbett, M. R. McGuigan, N. Etxebarria and R. U. Newton (2008). "Relative Importance of Strength, Power, and Anthropometric Measures to Jump Performance of Elite Volleyball Players." Journal of Strength and Conditioning Research 22(3): 758-765.
80. Sheppard, J. M., T. J. Gabbett and L. C. R. Stanganelli (2009). "An Analysis of Playing Positions in Elite Men's Volleyball: Considerations for Competition Demands and Physiologic Characteristics." Journal of Strength and Conditioning Research 23(6): 1858-1866.
81. Singh, H., R. S. Rana and S. S. Walia (1987). Effect of strength and flexibility on performance in men's gymnastics. World identification systems for gymnastic talent. B. Petiot, J. H. Salmela and T. B. Hoshizaki. Montreal, Sport Psyche editions: 118-120.
82. Sleeper, M. D., M. Beers, M. Erwin, J. Meyer, J. Passaglia, E. Schornak, M. Strobel and M. Wildeboer (2006). "The Gymnastics Functional Measurement Tool: An Instrument for the Physical Assessment of Competitive Gymnasts." Medicine and Science in Sports and Exercise 38(5): S232-S232.
83. Sleivert, G. G. and H. A. Wenger (1993). "Physiological Predictors of Short-Course Triathlon Performance." Medicine and Science in Sports and Exercise 25(7): 871-876.
84. Smits-Engelsman, B. C. M. (1998). Movement ABC; Nederlandse Handleiding [Dutch manual Movement ABC]. *Lisse, The Netherlands: Swets, Zeitlinger*.
85. Sol, J. B. M. (1987). The Bisdom/Sol aptitude test for female gymnasts. World identification systems for gymnastic talent. B. Petiot, J. H. Salmela and T. B. Hoshizaki. Montreal, Sport Psyche editions: 113-117.
86. Srhoj, V., N. Rogulj, N. Zagorac and R. Katic (2006). "A new model of selection in women's handball." Collegium Antropologicum 30(3): 601-605.
87. Stanganelli, L. C. R., A. C. Dourado, P. Oncken, S. Mancan and S. C. da Costa (2008). "Adaptations on Jump Capacity in Brazilian Volleyball Players Prior to the under-19 World Championship." Journal of Strength and Conditioning Research 22(3): 741-749.
88. Sterkowicz, S., G. Lech, T. Palka, A. Tyka, K. L. Sterkowicz-Przybycien, Z. Szygula and A. Klys (2011). "Body Build and Body Composition Vs. Physical Capacity in Young Judo Contestants Compared to Untrained Subjects." Biology of Sport28(4): 271-277.
89. Suriano, R. and D. Bishop (2010). "Physiological attributes of triathletes." Journal of Science and Medicine in Sport 13(3): 340-347.
90. Tsolakis, C., Kostaki, E., & Vagenas, G. (2010). Anthropometric, flexibility, strength-power, and sport specific correlates in elite fencing1. *Perceptual and motor skills*, *110*(3C), 1015-1028.
91. Vaeyens, R., R. M. Malina, M. Janssens, B. Van Renterghem, J. Bourgois, J. Vrijens and R. M. Philippaerts (2006). "A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project." British Journal of Sports Medicine 40(11): 928-934.
92. Van Dyck, L., Paulissen, A., Wijtzes, A. (2008). Herkennen en ontwikkelen van turntalent in Vlaanderen.
93. Van Schuylenbergh, R., B. V. Eynde and P. Hespel (2004). "Prediction of sprint triathlon performance from laboratory tests." Eur J Appl Physiol 91(1): 94-99.
94. Vandendriessche, J. B., R. Vaeyens, B. Vandorpe, M. Lenoir, J. Lefevre and R. M. Philippaerts (2012). "Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years)." Journal of Sports Sciences 30(15): 1695-1703.
95. Vandorpe, B., Vandendriessche, J., Lefèvre, et al., (2011). The KörperkoordinationsTest für Kinder: reference values and suitability for 6–12‐year‐old children in Flanders. Scandinavian journal of medicine & science in sports, 21(3), 378-388.

96. Vandorpe, B., J. Vandendriessche, R. Vaeyens, J. Pion, J. Lefevre, R. Philippaerts and M. Lenoir (2011). "Factors Discriminating Gymnasts by Competitive Level." International Journal of Sports Medicine 32(8): 591-597.
97. Vandorpe et al., 2012, Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach, Journal of Science and Medicine in Sports, 5, 3, p 220-225
98. Van Waelvelde, H., De Weerdt, W., De Cock, P., & Smits-Engelsman, B. C. M. (2004). Aspects of the validity of the Movement Assessment Battery for Children. *Human movement science*, *23*(1), 49-60.
99. Vila, H., C. Manchado, N. Rodriguez, J. A. Abraldes, P. E. Alcaraz and C. Ferragut (2012). "Anthropometric Profile, Vertical Jump, and Throwing Velocity in Elite Female Handball Players by Playing Positions." Journal of Strength and Conditioning Research 26(8): 2146-2155.
100. Visnapuu, M. and T. Jurimae (2009). "Relations of Anthropometric Parameters with Scores on Basic and Specific Motor Tasks in Young Handball Players." Perceptual and Motor Skills 108(3): 670-676.
101. Werkiani, M. E., B. Zakizadeh, M. S. Feizabadi, F. N. Golsefidi and M. Rahimi (2012). "Review of the effective talent identification factors of badminton for better teaching to success." World Conference on Learning, Teaching & Administration - 2011 31: 834-836.
102. Westfall, B., T. Kiesenhofer, M. Martins, J. B. Bertrand, D. Yachiw, K. Murphy and R. Quan. (2012). "Long Term Athlete Development Model, Table Tennis 4 life."
From http://canadiansportforlife.ca/sites/default/files/resources/TableTennisEng_0.pdf.
103. Williams, A. M. and T. Reilly (2000). "Talent identification and development in soccer." Journal of Sports Sciences 18(9): 657-667.
104. Wolstencroft (2002). Talent identification and development: An Academic Review. Edinburgh: Sport Scotland
105. Wonisch, M., P. Hofmann, G. Schwaberger, S. P. von Duvillard and W. Klein (2003). "Validation of a field test for the non-invasive determination of badminton specific aerobic performance." British Journal of Sports Medicine 37(2): 115-118.
106. Zaccagni, L., N. Onisto and E. Gualdi-Russo (2009). "Biological characteristics and ageing in former elite volleyball players." Journal of Science and Medicine in Sport 12(6): 667-672.
107. Zagatto, A. M., E. A. Morel and C. A. Gobatto (2010). "Physiological Responses and Characteristics of Table Tennis Matches Determined in Official Tournaments." Journal of Strength and Conditioning Research 24(4): 942-949.
108. Zapartidis, I., T. Toganidis, I. Vareltzis, C. Triantafillos, P. Kororos and D. Skoufas (2009). "Profile of young female handball players by playing position." Serbian Journal of Sports sciences 3(1-4): 53-60.
109. Ziv, G. and R. Lidor (2009). "Physical Attributes, Physiological Characteristics, On-Court Performances and Nutritional Strategies of Female and Male Basketball Players." Sports Medicine 39(7): 547-568.
110. Ziv, G. and R. Lidor (2010). "Vertical jump in female and male volleyball players: a review of observational and experimental studies." Scandinavian Journal of Medicine & Science in Sports 20(4): 556-567.
111. Zuniga, J., T. J. Housh, C. L. Camic, M. Mielke, C. R. Hendrix, G. O. Johnson, D. J. Housh and R. J. Schmidt (2011). "Yearly Changes in the Anthropometric Dimensions of Female High School Gymnasts." Journal of Strength and Conditioning Research 25(1): 124-128.

1.3 OUTLINE OF THE ORIGINAL RESEARCH

Talent identification programs are implemented worldwide to identify the better athletes at an early stage. Due to scaling effects small countries have difficulties to compete with the traditional nations that generally take the lead in the medal rankings. The limited talent pool implies that sports clubs and federations in small countries cannot afford to miss a single talent. The cost benefit analysis indicates that testing many children is expensive. There have been attempts to develop talent identification systems like in Australia and Scotland, but for large countries, the scope of such a project is too big. Small countries can reverse this problem into an advantage by not skipping this step in their talent policy.

The detection of the ‘better mover’ is the first phase in an optimal talent system that is based upon the collection of generic information that is of use for all sports bodies. Making an overall assessment is however not popular in a sport-specific environment as this type of investment is not moneymaking immediately. The general aim of this dissertation is to facilitate the sport choices made from primary schools to elite level. A talent detection and identification system cannot be developed and implemented "out of the blue”. There is a need for accurate data on morphological, physical, coordinative and maturity characteristics in a large sample of children and young athletes of different levels.

In order to test the value of a generic test battery, it was a deliberate choice to conduct research in different sports and children/athletes of different levels. The advantages of generic screening are multiple. First it has never been studied to what extent children in the early years of sports participation already possess sport specific characteristics that make them more fit to one or another sport. This is due to a lack of attention for investigating these characteristics in children that have not been identified as talents in one particular sport. Therefore, in the first study we documented to what extent sport specific characteristics are present in children in the early career. It is hypothesised in the first study that

a) sports participation contributes positively to the child’s general physical fitness and motor profile;

b) primary school children, 9 to 12 year old, who are participating in a specific sport, already exhibit performance characteristics in line with the requirements of that particular sport;

c) children with a more extended training history exhibit more pronounced anthropometric, physical fitness and motor coordination profiles that match their specific sport characteristics.

Based upon an objective and generic screening, children who have not yet started their sports training can be orientated to one or more sports and promising athletes of various ages can be guided throughout their development. In the same line of thinking, the potential of such a generic test battery in the reorientation process of young athletes is investigated in studies 2 an 3. It is studied to what extent characteristics of athletes of different or related sports either discriminate them from other atletes, or allow to find enough communalities to consider a potential reorientation towards another sport. To clarify the value of this, worldwide skipped phase of reorientation, the following hypotheses are formulated:

a) It is possible to allocate athletes to a variety of sports based on a unique combination of test scores, using a non-sport specific generic test battery;

b) It is possible to allocate athletes of related sports into their specific discipline.

The Flemish Sports Compass also provides a motivated advice for sports choice at young age. Attrition in sport is always been attributed to social or mental characteristics. Assuming that poor performance scores at least partly affect the social or mental pressure that leads to dropout, we hypothesise that talent identification test batteries can provide insights into future dropout and accentuate critical talent characteristics. If generic tests were able to predict attrition or elite performance at baseline, it would be possible to develop strategies to keep children involved in sports. These issues are focused upon in studies 4 and 5. The main hypothesis is that the FSC enables the identification of critical characteristics that allow the prediction of attrition and dropout in elite female gymnastics.

Our final study (study 6) focused on the absolute elite level. The ultimate validation of any talent identification system lies in proportion of identified athletes that reach the top. We hypothesized that female volleyball players who ultimaltely reach the top, show differences in generic, i.e. non-volleyball specific characteristics, when compared to peers that fail to reach this level by a small margin. .

This dissertation covers the range from orientation to performance prediction and the hypotheses described before are displayed in Figure 23.

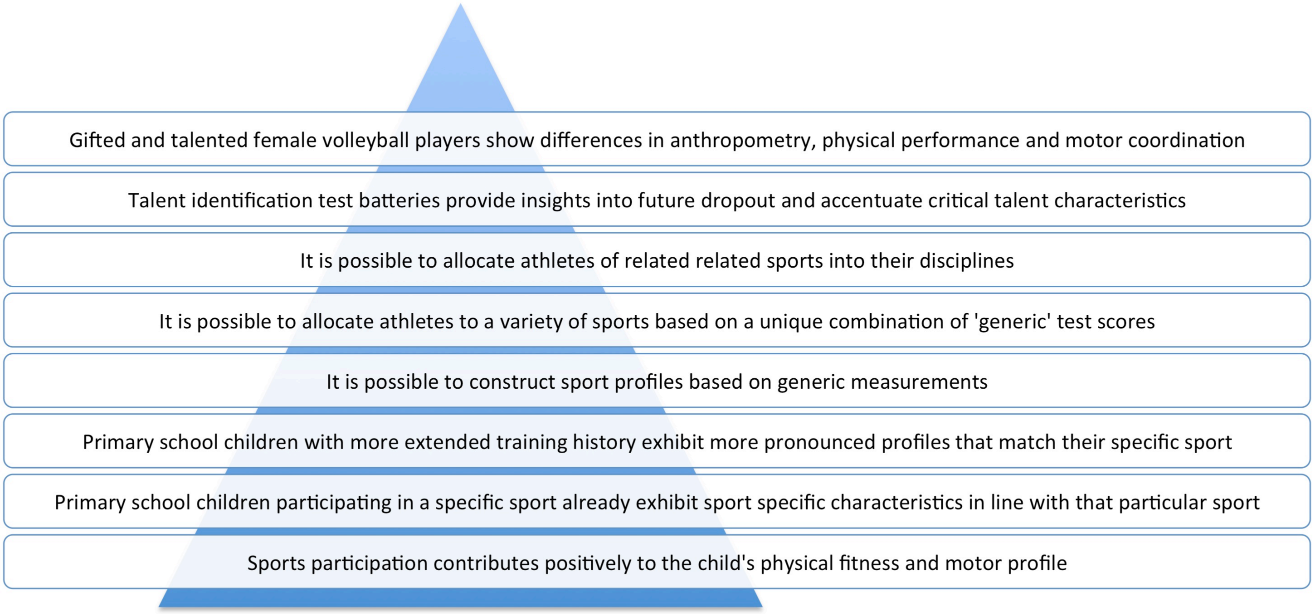
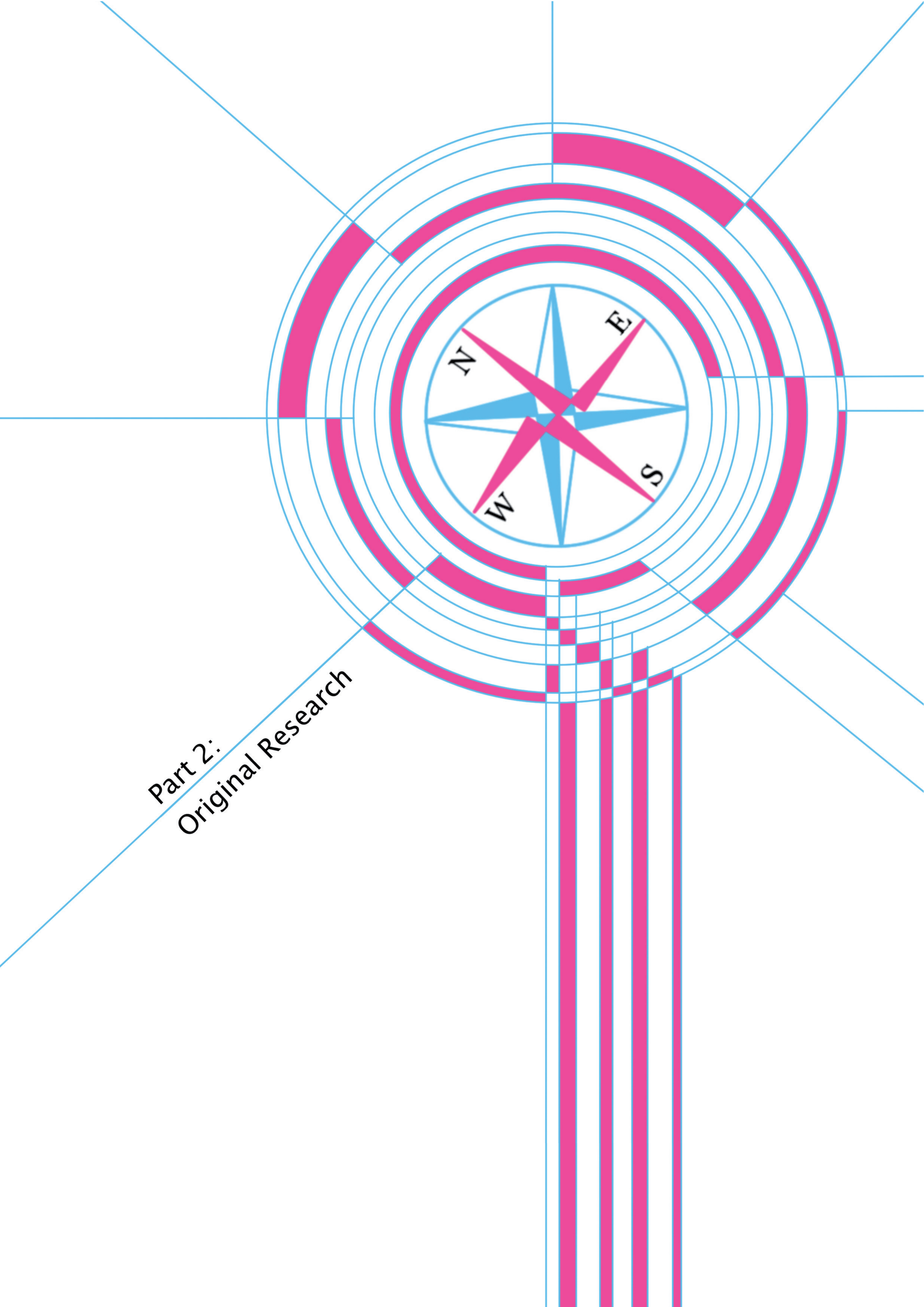


Figure 23: Outline for the original research and hypotheses



Part 2: Original Research

Je hebt in het leven maar één talent nodig,

Het talent om je droom te vinden

(Jacques Brel, zanger)

2.1 TALENT DETECTION

2.1.1 PAPER 1: ANTHROPOMETRIC, PHYSICAL FITNESS AND MOTOR COORDINATIVE CHARACTERISTICS OF 9 TO 11 YEAR OLD CHILDREN PARTICIPATING IN A WIDE RANGE OF SPORTS

PLOS
ONE
A peer-reviewed, open access journal

Katrijn Opstoel*, Johan Pion*, Marije Elferink-Gemser, Esther Hartman, Bas Willemse,

Renaat Philippaerts, Chris Visscher, Matthieu Lenoir.

(Katrijn Opstoel and Johan Pion share first authorship)

Published: May 15, 2015

Abstract

Objectives

The aim of this study was to investigate to what extent 9 to 11 year old children participating in a specific sport already exhibit a specific anthropometric, physical fitness and motor coordination profile, in line with the requirements of that particular sport. In addition, the profiles in children with a different training volume were compared and possible differences in training hours per week between children from a low, moderate, and high level of physical fitness and motor coordination were investigated.

Methods and results

Data of 620 children, 347 boys and 273 girls, who participated in the Flemish Sports Compass, were used. Only the primary sport of each child was considered and six groups of sports (Ball sports, Dance, Gymnastics, Martial arts, Racquet sports and Swimming) were formed based on common characteristics. Measurements consisted of 17 tests. Independent T-tests and Mann-Whitney U-tests revealed few differences between the groups of sports and the discriminant analyses with the moderate and low active group did not show any significant results ($p > .05$). However, when discriminating among the high active children, a 85.2 % correct classification between six groups of sports was found (Wilks' $\Lambda = .137$ and $p < .001$). Finally, children performing under average on the tests spent significantly fewer hours in sport per week (2.50 ± 1.84 hours) compared to the children performing best (3.25 ± 2.60 hours) ($p = .016$) and the children performing above average (2.90 ± 1.96 hours) ($p = .029$) on physical fitness and motor coordination.

Discussion

The study showed that in general, children at a young age do not exhibit sport-specific characteristics, except in children with a high training volume. It is possible that on the one hand, children have not spent enough time yet in their sport to develop sport-specific qualities. On the other hand, it could be possible that they do not take individual qualities into account when choosing a sport.

Introduction

The benefits of sports participation on physical and mental health are widely recognized (1-5). Sports participation not only positively influences anthropometric measures like body weight and body composition (6), children's health also improves in terms of physical fitness (5, 7, 8) which can be considered one of the most important markers of health (5). In addition, sports participation at a young age positively contributes to the development of the child's motor coordination since involvement in physical activity provides more opportunities to learn and refine motor skill executions (7, 9). In children who are actively involved in sports, differences in levels of physical fitness and motor coordination can partly be explained by the amount of hours spent within the sport. For example, Fransen and colleagues (10) found a positive effect of the amount of training hours per week on flexibility (sit and reach), explosive leg power (standing broad jump) and motor coordination (Körperkoordinationstest für Kinder) in 10 to 12 year old boys.

In addition to the positive influence on the child's general physical profile, involvement in sport is also associated with the development of sport-specific characteristics. The well-documented comparison between adolescent athletes from different types of sports makes it clear that each sport is, to some extent, unique in terms of physical prerequisites, e.g., (11-17). For example, soccer players demonstrate high levels of both upper and lower body strength for sport-specific actions including throwing-in and kicking the ball (15), while height is the key ingredient to make it to the top in volleyball (12), and motor coordination appears to be crucial in gymnastics (17). These sport-specific characteristics make it possible to discriminate between athletes of different sports. A discriminant analysis of anthropometric variables and physical fitness characteristics among adolescent female figure skaters, swimmers, volleyball players and tennis players, showed that figure skaters can be discriminated from the other athletes based upon their lower body mass and height, fewer push-ups and lower maximal girth of the biceps (18). Similarly, Pion and colleagues (19) studied the discriminative power of 22 anthropometric, physical fitness and motor coordination measurements and reported a 96.4 % correct classification for 141 adolescent Flemish boys into nine different sports. In sum, the unique characteristics of elite adolescent athletes from different sports have been widely demonstrated, thereby providing important information from the viewpoint of talent detection, identification, and development. However, most of these studies have focused on adolescent and adult athletes that have already benefitted from a considerable training history that has at least in part shaped their current anthropometric, physical fitness and motor coordination profile. The question remains to what degree these specific characteristics are already present in children with a limited training history.

Consequently, the central question in this paper is to what extent young children participating in a specific sport already exhibit a specific anthropometric, physical fitness and motor coordination profile in line with the requirements of that particular sport. This is a relevant question from the perspective of health-enhancing physical activity, as well as from the viewpoint of talent identification. A match between the sport-specific characteristics and the individual anthropometric, physical fitness and motor profile of a child is more than likely an efficient protection from early dropout from sports participation because the child will experience early success in this sport (20). Children experiencing early success in a particular sport, not necessarily at a (high) competitive level, might increase their chances for sustained sports participation and an active lifestyle later on (21). With respect to talent identification, children with a profile that matches the requirements of a specific sport from a young age on will more likely continue training and by consequence have better chances on an optimal talent development pathway.

The first aim of the present study was to examine whether 9 to 11 year old children already involved in sports participation demonstrate sport-specific characteristics in terms of anthropometry, physical fitness and motor coordination. The authors expect that sport-specific profiles are generally not distinctive enough at a young age.

Since training inevitably shapes the individual profiles, the second purpose is to construct sport profiles based on 17 performance measurements and to compare them in children with a low, moderate, and high training volume. Ericsson's theory of deliberate practice (22) states that the level of expertise obtained by elite athletes is at least in part a function of the amount of structured practice. It was expected that children with a more extended training history would exhibit more pronounced anthropometric, physical fitness and motor coordination profiles matching the specific sport.

In the third aim, we investigated the difference in training hours per week between children from a low, moderate, and high level of physical fitness and motor coordination. Since sports participation contributes positively to the child's general physical fitness and motor profile, it was expected that children performing better on physical fitness and motor coordination, spend more hours per week in their sport.

Materials and Methods

Ethics statement

The Ethics Committee of the Ghent University Hospital approved the study and written informed parental consent was obtained for all participants (23).

Participants

The data for this study is part of the Flemish Sports Compass (FSC), a cooperation of the Flemish government and Ghent University that was started in 2007 and ended in 2012 (10, 19, 23-25). Twenty-six primary schools were randomly selected from the five Flemish provinces of the Flemish region and the Brussels-capital region (for details see (23)). A sample of 620 children (10.30 ± 0.88 years), 347 boys and 273 girls, who participated in the FSC and who were involved in at least one sport, were included in the present study. A total of 343 children practiced one sport, 181 children were involved in two different sports and 96 children practiced three different sports. Within this study, the primary sport, i.e. the sport in which the child spends most of the time, was selected, which resulted in a total of 25 different sports.

Groups of sports

The 25 different sports were initially divided into 8 sport groups based on common characteristics (see (19)). Recreational running (n=12) and track and field (n=23) were placed under 'Athletics'. Basketball (n=17), korfball (n=3), soccer (n=163) and volleyball (n=10) were combined as 'Ball sports' based on the common character of ball skills. The different types of dancing including ballet (n=19), folk dance (n=6), jazz dance (n=13), modern dance (n=19) and other dance (n=54) were combined into the category 'Dance'. Acrobatics (n=11), acro gymnastics (n=6) and artistic gymnastics (n=38) formed the category 'Gymnastics'. Judo (n=21), karate (n=25) and tae kwon do (n=5) were combined into the category 'Martial arts' and badminton (n=4) and tennis (n=42) were both considered 'Racquet sports'. The rest of the sports did not fit into any of the aforementioned categories: recreational bicycling (n=15); figure/ice skating (n=4); field hockey (n=8); horse riding (n=35); skiing (n=6) and swimming (n=61). Therefore these sports were combined into the category 'Other sports' except for swimming. Based on the amount of swimmers (n=61) and the distinct profile of the sport, swimming was considered as a category of its own. The groups 'Athletics' and 'Other Sports' were only considered for the descriptive part of this study and not included for other analyses based on the diversity of sport-specific skills within the group.

Measurements

A subset of 17 tests of the FSC was used in the present study. Trained examiners assessed the children in accordance with the test guidelines of the FSC protocol.

Anthropometry

Body height (BH) and sitting height (SH) (0,1 cm) were both measured using portable stadiometers (Harpenden, Holtain Ltd., Crymych, UK). Body weight (BW) (0.1 kg) and body fat percentage (BF) were measured using a bio-electrical impedance device (Tanita, BC-420SMA). Body mass index (BMI) was calculated using the following formula: BMI = (body weight/body height^2).

Physical fitness

Endurance. Cardiovascular endurance was obtained using the 20-m endurance shuttle run test (SR) (0.5 min) (EUROFIT) (26). Children had to run back and forth between two lines 20 meters apart, at a speed that was imposed by means of beep signals. As the test progressed, the time provided to reach the other side gradually decreased, requiring the children to run faster and faster. Failure to cross the other line before or on the beep was only allowed once. The SR test has adequate values for validity, ranging from .68 to .76, and reliability, ranging from .68 to .84, measured in 4 to 18 year old children (27).

Flexibility. The sit-and-reach test (SAR) (EUROFIT) (26) was used to assess children's hamstring and lower back flexibility, with an accuracy of 0.5 cm. The SAR test has adequate validity and reliability values ranging from .60 to .73 and .70 to .98 respectively, measured in 4 to 18 year old children (27). Shoulder flexibility (SF) (0.5 cm) was assessed using the shoulder rotation test (24, 28, 29). A lower score indicated better flexibility. The shoulder rotation test proved to be reliable with a test-retest reliability coefficient between .73 and .96, measured in 9 to 13 year old children (28).

Speed and agility. The 10x5 shuttle run test (10x5 SR) (EUROFIT) (26) was used to measure the child's speed and agility. The time children needed to run back and forth as quickly as possible between two lines 5 meters apart, 10 times in a row, reflected their speed and agility. The 10x5 SR test has adequate values for validity, ranging from .62 to .85, and reliability, ranging from .62 to .96, measured in 4 to 18 year old children (27).

Strength. This study included four tests to measure children's strength. Both standing broad jump (SBJ) and counter movement jump (CMJ) measured the child's explosive leg power with an accuracy of 1.0 cm and 0.1 cm respectively (EUROFIT) (26). The SBJ showed adequate values for validity and reliability ranging from .52 to .78 and .66 to .97 respectively (27). The CMJ showed high values for validity and reliability with .87 for internal consistency and a Cronbach's α of .98 for reliability (30). The highest of three counter movement jumps, measured by means of an Optojump device (Microgate, Bolzano, Italy) (31), was used for further analysis. Muscular strength and muscular endurance of the upper body were obtained using sit-ups (SU) and knee push-ups (KPU) (BOT-2) (32). The participants were asked to perform as many repetitions as possible within 30 seconds. The SU and KPU proved to be reliable and valid tests for strength with a test-retest reliability coefficient of .88, measured in 8 to 12 year old children, and an intercorrelation coefficient of .87, measured in 8 to 11 year old children (32).

Motor coordination

Gross motor coordination

Gross motor coordination was measured using the Körperkoordinationstest für Kinder (KTK) (33). Three subtests were included in this study. For balance, children were asked to walk backwards (WB) on three different balance beams with decreasing width. Three attempts on each of the three balance beams resulted in a total score of maximum 72. For the second test, children had to jump sideways (JS) with both feet together over a wooden slat, as fast as possible. The sum of two attempts of 15 seconds resulted in a total score. Finally, for the test moving sideways (MS), children were asked to make as much relocations as possible within 20 seconds by means of two 20 by 20 cm square boxes. The sum of two attempts resulted in a total score. The scores of each of the three subtests were then converted into age- and gender- specific motor quotients (25). The KTK proved to be a reliable instrument with test-retest reliability coefficients of .80, .95 and .84 for WB, JS and MS respectively.

Upper limb coordination

Upper limb coordination was measured by dribbling a tennis ball (BD) with alternating hands 10 times in a row (Short form Bot-2) (32). The score equals the number of correct dribbles with a maximum of 10. When the child did not reach the maximum score of 10, a second trial was conducted. The upper-limb coordination subtest showed adequate values for reliability and validity with a test-retest reliability coefficient of .59, measured in 8 to 12 year old children, and an intercorrelation coefficient of .82, measured in 8 tot 11 year old children (32).

Sports participation

The Flemish Physical Activity Computerized Questionnaire (FPACQ) (34) was used to obtain the type of organized sport children participated in and the amount of training hours per week at the time of data collection. The primary sport was taken into account for this study. The FPACQ proved to be a reliable and valid instrument to measure the amount of hours of sports participation per week with a test-retest reliability coefficient of .74 and a Pearson correlation coefficient of .52 for concurrent validity (34). To ascertain the validity, the FPACQ was compared to the output measures of the Computer Science and Applications uniaxial accelerometer.

Data analysis

Data were analyzed using SPSS version 20.0. Significance level was set at $P < .05$. Descriptive statistics were obtained for the absolute values of each of the 17 performance measurements for the 25 different sports separately and for the eight groups of sports. To allow the comparison of the results of children from different ages (9, 10 and 11 year old children), standardized Z-scores were calculated using the age specific means for each of the 17 variables.

Sport-specific characteristics

To examine whether 9 to 11 year old children already involved in sports participation demonstrate sport-specific characteristics in terms of anthropometry, physical fitness and motor coordination Independent T-tests (in case of normally distributed data) or Mann-Whitney U-tests (in case of not normally distributed data) were performed. The Shapiro-Wilk test was used to test for normality of data. For each of the 17 performance measurements, the Z-score of each of the six groups of sports (Ball sports, Dance, Gymnastics, Martial arts, Racquet sports and Swimming) was compared to an overall Z-score of the remaining groups (e.g., body height of the ball sport players vs. body height of the non-ball sport players).

Role of training in sport-specific profiles

Three discriminant analyses were performed to construct and subsequently compare profiles of six different groups of sports in children spending one hour or less per week (low active), children spending between one and five hours per week (moderate active) and children spending five or more hours per week (high active). The profiles are based on the Z-scores of the 17 performance measurements, which were inserted as the independent variables. The six groups of sports were used as grouping variable. Discriminant functions and the amount of correctly classified children were calculated.

Role of training in PQ and MQ levels

To examine the possible differences in training hours per week between children from a low, moderate, and high level of physical fitness and motor coordination, a One-way ANOVA (in case of normally distributed data) or a Kruskal-Wallis test and three subsequent Mann-Whitney U-tests (in case of not normally distributed data) were performed. The Shapiro-Wilk test was used to test for normality of data. The following three groups were considered: the under average performers with a physical fitness quotient (PQ) and/or motor quotient (MQ) of .0 or lower, children performing above average with a PQ and/or MQ between .0 and .5, and the best performers with a PQ and MQ of .5 or higher. PQ and MQ were calculated using the Z-scores of each of the physical fitness and motor coordination variables (PQ = Z-SR + Z-SF + Z-SAR + Z-10x5 SR + Z-SBJ + Z-CMJ + Z-SU + Z-KPU and MQ = Z-JS + Z-MS + Z-WB + Z-BD).

Results

Descriptive statistics

Table 8 shows the absolute values of the anthropometric measures body height (BH), sitting height (SH), body weight (BW), body fat percentage (BF), and body mass index (BMI) for each of the 25 different sports and the eight groups of sports. Table 9 presents the absolute values of the physical fitness measures endurance shuttle run (SR), shoulder flexibility (SF), sit-and-reach (SAR), 10x5 shuttle run (10x5 SR), standing broad jump (SBJ), counter movement jump (CMJ), sit-ups (SU) and knee push-ups (KPU) for each of the 25 different sports and the eight groups of sports. Table 10 displays the absolute values of the motor coordination measures jumping sideways (JS), moving sideways (MS), walking backwards (WB) and ball dribbling (BD) for each of the 25 different sports and the eight groups of sports.

Table 8: Descriptive statistics (mean and standard deviation) for the anthropometric variables.

	n	Body height (cm)	Sitting height (cm)	Body weight (kg)	Body fat (%)	BMI (kg/m^2)
Athletics	**35**	**141,03 ± 10,27**	**73,58 ± 4,66**	**35,12 ± 10,14**	**18,45 ± 5,99**	**17,35 ± 2,75**
Recreational running	12	139,30 ± 11,59	73,19 ± 5,23	37,38 ± 12,23	20,15 ± 7,24	18,78 ± 2,99
Track and field	23	141,93 ± 9,67	73,78 ± 4,45	33,93 ± 8,93	17,57 ± 5,18	16,61 ± 2,36
Ball sports	**193**	**141,65 ± 7,21**	**74,26 ± 3,55**	**34,90 ± 6,98**	**17,24 ± 6,00**	**17,29 ± 2,55**
Basketball	17	143,60 ± 7,60	75,04 ± 3,24	38,04 ± 6,61	19,55 ± 6,62	18,39 ± 2,28
Korfball	3	142,53 ± 7,43	75,10 ± 3,73	35,43 ± 2,25	16,03 ± 2,46	17,46 ± 0,80
Soccer	163	141,36 ± 6,92	74,14 ± 3,50	34,33 ± 6,71	16,71 ± 5,80	17,09 ± 2,54
Volleyball	10	142,71 ± 10,97	74,63 ± 4,90	38,65 ± 10,53	22,18 ± 6,40	18,66 ± 3,00
Dance	**111**	**142,38 ± 7,54**	**74,44 ± 3,93**	**34,83 ± 7,47**	**18,43 ± 6,27**	**17,03 ± 2,47**
Ballet	19	145,42 ± 8,10	75,38 ± 3,62	35,62 ± 7,34	17,58 ± 5,52	16,68 ± 1,94
Folk dance	6	143,72 ± 9,90	75,03 ± 5,50	34,87 ± 7,76	18,52 ± 8,14	16,85 ± 3,40
Jazz dance	13	139,45 ± 7,67	73,30 ± 3,31	34,69 ± 8,48	20,37 ± 6,34	17,62 ± 2,71
Modern dance	19	141,57 ± 7,69	74,45 ± 5,08	32,63 ± 6,81	17,38 ± 6,44	16,13 ± 2,21
Other dance	54	142,15 ± 6,88	74,32 ± 3,58	35,36 ± 7,59	18,62 ± 6,34	17,34 ± 2,53
Gymnastics	**55**	**141,37 ± 8,10**	**73,67 ± 3,89**	**34,13 ± 7,00**	**17,56 ± 6,23**	**16,94 ± 2,38**
Acrobatics	11	143,07 ± 7,97	74,76 ± 3,29	37,35 ± 7,92	19,89 ± 7,80	18,12 ± 3,05
Acro gymnastics	6	137,90 ± 5,21	71,63 ± 3,08	31,28 ± 3,45	18,37 ± 2,11	16,42 ± 1,07
Artistic gymnastics	38	141,43 ± 8,50	73,67 ± 4,10	33,64 ± 6,95	16,76 ± 6,11	16,68 ± 2,26
Martial arts	**51**	142,87 ± 8,44	74,68 ± 3,84	35,89 ± 7,25	18,56 ± 5,65	17,45 ± 2,26
Judo	21	142,10 ± 7,94	74,05 ± 4,12	34,49 ± 7,10	17,89 ± 6,09	16,93 ± 2,20
Karate	25	143,13 ± 9,10	75,28 ± 3,86	36,28 ± 6,59	18,37 ± 5,15	17,62 ± 2,12
Tae kwon do	5	144,76 ± 8,32	74,36 ± 2,40	39,82 ± 10,69	22,34 ± 5,80	18,73 ± 3,06
Other sports	**68**	**141,25 ± 6,97**	**74,13 ± 3,86**	**34,85 ± 7,50**	**19,33 ± 7,83**	**17,37 ± 3,02**
Bicycling (recreational)	15	142,25 ± 6,18	74,55 ± 2,99	40,09 ± 9,74	23,17 ± 10,78	19,67 ± 4,01
Figure/Ice skating	4	143,53 ± 12,76	74,18 ± 6,55	35,73 ± 5,57	20,08 ± 2,35	17,31 ± 1,45
Field hockey	8	140,29 ± 6,81	73,51 ± 2,75	33,31 ± 5,59	17,65 ± 8,56	16,97 ± 3,11
Horse-riding	35	140,83 ± 7,04	74,07 ± 4,35	32,75 ± 5,77	17,59 ± 5,91	16,44 ± 2,02
Skiing	6	140,95 ± 5,85	74,18 ± 2,93	35,47 ± 8,99	21,67 ± 8,66	17,69 ± 3,44
Racquet sports	**46**	141,61 ± 6,59	73,77 ± 3,10	33,79 ± 5,59	17,99 ± 5,74	16,78 ± 2,02
Badminton	4	143,78 ± 3,54	73,35 ± 0,82	36,18 ± 3,73	19,28 ± 6,30	17,55 ± 2,24
Tennis	42	141,41 ± 6,80	73,81 ± 3,24	33,56 ± 5,71	17,87 ± 5,75	16,71 ± 2,02
Swimming	**61**	**141,87 ± 8,29**	**74,55 ± 4,45**	**35,56 ± 7,56**	**19,34 ± 6,42**	**17,51 ± 2,56**

Table 9: Descriptive statistics (mean and standard deviation) for the physical fitness variables.

	n	SR (min)	SF (cm)	SAR (cm)	10x5 SR (s)	SBJ (cm)	CMJ (cm)	SU (n/30s)	KPU (n/30s)
Athletics	**35**	**5,83 ± 2,22**	**91,4 ± 15,1**	**20,1 ± 6,6**	**22,0 ± 2,0**	**141,7 ± 20,7**	**20,4 ± 4,8**	**22,8 ± 7,0**	**26,2 ± 6,3**
Recreational running	12	5,63 ± 2,30	87,3 ± 20,4	23,1 ± 7,1	21,8 ± 2,2	143,6 ± 21,9	19,3 ± 4,5	20,7 ± 9,1	25,3 ± 7,1
Track and field	23	5,93 ± 2,22	93,5 ± 11,4	18,5 ± 5,9	22,1 ± 1,8	140,7 ± 20,5	20,9 ± 4,9	23,9 ± 5,6	26,6 ± 5,9
Ball sports	**193**	**6,05 ± 2,38**	**91,1 ± 17,5**	**18,7 ± 5,7**	**21,9 ± 1,6**	**141,0 ± 20,5**	**20,5 ± 4,1**	**22,6 ± 6,8**	**26,5 ± 6,4**
Basketball	17	5,62 ± 1,89	92,7 ± 20,1	19,6 ± 6,2	22,3 ± 1,5	133,8 ± 15,9	19,4 ± 2,9	22,8 ± 7,4	26,9 ± 6,3
Korfball	3	7,50 ± 1,32	95,0 ± 8,7	17,3 ± 2,1	20,0 ± 1,4	165,3 ± 9,5	25,0 ± 3,3	27,7 ± 0,6	28,0 ± 9,0
Soccer (field)	163	6,11 ± 2,43	90,6 ± 17,4	18,5 ± 5,7	21,9 ± 1,5	141,7 ± 20,6	20,6 ± 4,1	22,6 ± 6,7	26,3 ± 6,4
Volleyball	10	5,35 ± 2,57	96,4 ± 16,6	20,6 ± 5,8	21,9 ± 2,2	135,0 ± 22,4	19,7 ± 3,9	19,8 ± 8,1	27,4 ± 6,5
Dance	**111**	**5,35 ± 2,37**	**88,7 ± 13,7**	**21,2 ± 5,6**	**22,0 ± 1,5**	**140,2 ± 21,1**	**20,0 ± 4,2**	**22,9 ± 6,4**	**25,3 ± 7,0**
Ballet	19	5,74 ± 2,40	87,3 ± 11,3	19,8 ± 5,1	21,5 ± 1,4	147,8 ± 21,3	21,8 ± 4,0	23,9 ± 7,2	27,3 ± 5,5
Folk dance	6	3,83 ± 1,21	91,0 ± 11,7	18,9 ± 3,3	22,1 ± 1,3	124,8 ± 16,6	17,9 ± 4,8	20,5 ± 6,9	22,8 ± 7,5
Jazz dance	13	5,04 ± 1,80	86,0 ± 11,5	22,3 ± 5,3	22,1 ± 1,2	141,3 ± 14,7	18,8 ± 3,9	22,8 ± 7,1	25,5 ± 6,9
Modern dance	19	4,11 ± 1,89	92,9 ± 10,4	22,7 ± 5,7	22,6 ± 1,3	131,2 ± 19,9	20,2 ± 4,5	24,7 ± 6,6	21,2 ± 6,0
Other dance	54	5,89 ± 2,53	88,1 ± 15,9	21,1 ± 5,9	21,9 ± 1,8	142,1 ± 21,8	19,9 ± 4,2	22,2 ± 5,7	26,3 ± 7,3
Gymnastics	**55**	**5,35 ± 2,18**	**87,3 ± 16,6**	**21,1 ± 7,8**	**21,9 ± 2,1**	**141,6 ± 24,5**	**21,5 ± 4,8**	**24,7 ± 8,5**	**26,4 ± 7,5**
Acrobatics	11	5,09 ± 1,88	93,3 ± 20,9	18,1 ± 10,8	22,3 ± 1,8	134,3 ± 26,0	21,0 ± 5,0	22,5 ± 7,1	28,3 ± 9,8
Acro gymnastics	6	5,75 ± 1,72	71,7 ± 8,2	29,4 ± 6,3	21,8 ± 0,8	156,8 ± 12,8	22,0 ± 3,6	30,0 ± 10,5	23,7 ± 5,2
Artistic gymnastics	38	5,37 ± 2,35	88,1 ± 14,9	20,7 ± 6,1	21,8 ± 2,3	141,3 ± 24,9	21,6 ± 5,0	24,6 ± 8,4	26,3 ± 7,1
Martial arts	**51**	**5,12 ± 2,04**	**91,4 ± 15,9**	**17,5 ± 6,9**	**22,5 ± 1,9**	**138,7 ± 23,9**	**20,3 ± 4,3**	**22,0 ± 7,2**	**26,5 ± 6,6**
Judo	21	5,05 ± 1,93	89,6 ± 13,5	19,0 ± 7,0	22,6 ± 1,9	139,4 ± 25,1	21,3 ± 4,3	21,7 ± 7,0	25,9 ± 7,7
Karate	25	5,16 ± 2,13	90,9 ± 17,8	17,1 ± 7,1	22,2 ± 1,7	140,0 ± 24,0	19,9 ± 3,8	22,9 ± 7,9	27,0 ± 5,6
Tae kwon do	5	5,20 ± 2,49	101,8 ± 13,8	13,1 ± 3,5	23,5 ± 2,5	129,8 ± 20,3	18,1 ± 5,7	18,6 ± 2,1	26,6 ± 8,0
Other sports	**68**	**4,67 ± 2,31**	**92,2 ± 15,2**	**19,0 ± 5,9**	**22,2 ± 1,8**	**137,7 ± 22,8**	**19,8 ± 4,5**	**22,8 ± 6,9**	**23,8 ± 6,2**
Bicycling (recreational)	15	4,40 ± 2,48	88,1 ± 14,0	20,0 ± 5,1	22,3 ± 2,0	132,3 ± 28,6	18,6 ± 5,2	21,7 ± 8,3	23,5 ± 7,6
Figure/Ice skating	4	4,50 ± 1,08	104,0 ± 6,4	21,6 ± 2,7	22,5 ± 1,3	141,3 ± 19,0	19,8 ± 2,9	25,8 ± 5,3	23,0 ± 2,7
Field hockey	8	4,94 ± 2,53	97,6 ± 8,8	18,6 ± 5,6	21,9 ± 1,5	132,4 ± 24,6	18,6 ± 3,1	22,1 ± 6,4	21,4 ± 5,9
Horse-riding	35	4,81 ± 2,45	91,4 ± 15,2	18,2 ± 5,9	22,2 ± 2,0	141,5 ± 21,8	20,5 ± 4,8	22,9 ± 6,7	24,5 ± 6,1
Skiing	6	4,25 ± 1,67	92,0 ± 25,0	20,3 ± 9,8	21,7 ± 0,7	134,0 ± 10,3	19,6 ± 2,0	23,5 ± 7,3	24,8 ± 5,0
Racquet sports	**46**	**5,39 ± 1,98**	**88,9 ± 14,0**	**17,6 ± 6,3**	**22,2 ± 1,7**	**139,8 ± 21,9**	**20,1 ± 4,1**	**22,0 ± 6,7**	**25,4 ± 6,3**
Badminton	4	3,88 ± 1,11	90,0 ± 17,8	18,0 ± 9,5	22,0 ± 1,7	141,0 ± 21,6	21,1 ± 4,3	25,3 ± 3,9	25,3 ± 3,9
Tennis	42	5,54 ± 2,00	88,8 ± 13,8	17,6 ± 6,1	22,2 ± 1,7	139,7 ± 22,2	20,0 ± 4,1	21,7 ± 6,8	25,4 ± 6,5
Swimming	**61**	**5,27 ± 1,88**	**90,2 ± 15,3**	**18,9 ± 7,0**	**22,6 ± 2,2**	**138,1 ± 20,5**	**20,4 ± 4,2**	**23,7 ± 6,2**	**26,2 ± 6,9**

SR: shuttle run, SF: shoulder flexibility, SAR: sit-and-reach, 10x5SR: 10x5 shuttle run, SBJ: standing broad jump, CMJ: counter movement jump, SU: sit-ups, KPU: knee push-ups

Table 10: Descriptive statistics (mean and standard deviation) for the motor coordination variables.

	n	Jumping sideways (n)	Moving sideways (n)	Walking backwards (n)	Ball dribbling (n)
Athletics	**35**	**62,9 ± 12,0**	**43,7 ± 7,4**	**49,9 ± 12,3**	**8,77 ± 2,04**
Recreational running	12	64,3 ± 11,1	45,9 ± 5,2	49,7 ± 8,9	9,08 ± 1,44
Track and field	23	62,1 ± 12,6	42,6 ± 8,2	50,0 ± 14,0	8,61 ± 2,31
Ball sports	**193**	**63,1 ± 11,0**	**42,6 ± 6,4**	**45,2 ± 13,2**	**9,02 ± 2,03**
Basketball	17	56,5 ± 12,0	42,4 ± 5,3	39,6 ± 8,0	9,88 ± 0,49
Korfball	3	74,7 ± 9,0	47,3 ± 4,5	60,7 ± 7,1	10,00 ± 0,00
Soccer (field)	163	63,7 ± 10,2	42,7 ± 6,3	45,4 ± 13,0	8,92 ± 2,09
Volleyball	10	60,6 ± 17,8	41,1 ± 8,4	46,1 ± 19,9	8,80 ± 2,57
Dance	**111**	**63,5 ± 10,9**	**43,3 ± 6,9**	**47,3 ± 13,6**	**8,39 ± 2,30**
Ballet	19	64,4 ± 11,4	42,7 ± 5,6	49,1 ± 8,4	8,42 ± 2,19
Folk dance	6	57,7 ± 13,5	42,0 ± 8,8	42,3 ± 11,0	8,17 ± 2,23
Jazz dance	13	60,9 ± 7,7	40,2 ± 5,1	46,6 ± 13,6	8,00 ± 2,55
Modern dance	19	61,4 ± 9,3	43,2 ± 4,9	43,5 ± 15,9	9,05 ± 1,68
Other dance	54	65,2 ± 11,5	44,4 ± 8,0	48,7 ± 14,4	8,26 ± 2,50
Gymnastics	**55**	**62,8 ± 12,5**	**43,2 ± 7,5**	**49,2 ± 13,9**	**8,38 ± 2,55**
Acrobatics	11	62,5 ± 14,1	42,8 ± 8,6	48,5 ± 16,7	7,91 ± 2,70
Acro gymnastics	6	61,2 ± 6,0	40,5 ± 6,1	52,7 ± 16,4	8,67 ± 2,07
Artistic gymnastics	38	63,2 ± 13,1	43,8 ± 7,5	48,9 ± 12,9	8,47 ± 2,62
Martial arts	**51**	**60,8 ± 12,7**	**40,8 ± 7,9**	**43,2 ± 13,5**	**8,00 ± 2,66**
Judo	21	61,1 ± 12,5	40,6 ± 8,9	41,5 ± 11,7	7,48 ± 2,77
Karate	25	62,0 ± 11,7	42,1 ± 5,9	45,1 ± 13,6	8,32 ± 2,51
Tae kwon do	5	53,8 ± 18,7	34,8 ± 10,5	41,0 ± 21,2	8,60 ± 3,13
Other sports	**68**	**60,6 ± 13,7**	**42,0 ± 6,8**	**47,9 ± 15,7**	**8,66 ± 2,36**
Bicycling (recreational)	15	62,0 ± 18,4	40,3 ± 8,0	46,1 ± 20,5	8,93 ± 1,94
Figure/Ice skating	4	51,0 ± 11,9	43,5 ± 4,8	41,5 ± 24,0	8,00 ± 2,83
Field hockey	8	63,1 ± 12,2	39,3 ± 3,4	45,4 ± 14,4	7,25 ± 3,01
Horse-riding	35	59,7 ± 12,4	42,5 ± 7,2	48,6 ± 13,2	8,94 ± 2,31
Skiing	6	65,2 ± 10,4	45,7 ± 3,8	56,2 ± 12,6	8,67 ± 2,42
Racquet sports	**46**	**64,1 ± 13,1**	**43,2 ± 7,0**	**46,9 ± 13,6**	**9,00 ± 1,90**
Badminton	4	66,5 ± 16,5	44,5 ± 7,7	42,8 ± 18,0	8,50 ± 3,00
Tennis	42	63,9 ± 12,9	43,1 ± 7,0	47,3 ± 13,4	9,05 ± 1,81
Swimming	**61**	**61,7 ± 11,5**	**41,5 ± 6,1**	**46,6 ± 14,4**	**9,02 ± 2,01**

Sport-specific characteristics

The Shapiro-Wilk test pointed out that the variables were not normally distributed (with p-values < 0.05), except for BH (p = 0.690), CMJ (p = 0.120) and MS (p = 0.260). Therefore, the Independent T-test was used for the variables BH, CMJ en MS. The Mann-Whitney U-test was used for the other 14 variables (BW, SH, BMI, BF, SF, SBJ, SAR, 10x5 SR, SU, KPU, SR, JS, WB and BD). The Mann-Whitney U-tests and Independent T-tests revealed that the ball sport players, dancers and swimmers did not show any significant differences from the other children (p > .05). The gymnasts however, performed significantly better on the CMJ (21.51 ± 4.81 cm vs. 20.32 ± 4.13 cm) (t(515) = 2.898 and p = .004) compared to the other children. Secondly, in martial arts, children performed significantly lower on the ball dribbling test (BD) (8.00 ± 2.66 correct dribbles vs. 8.79 ± 2.16 correct dribbles) (U = 9456.5, Z = -2.412 and p = .016) and scored significantly lower on moving sideways (MS) (40.76 ± 7.858 relocations vs 42.76 ± 6.673 relocations) (t(515) = -2.100 and p = .036) in comparison with the other children. Finally, children involved in racquet sports were significantly less flexible in terms of SAR (17.62 ± 6.31 cm vs. 19.46 ± 6.39 cm) (U = 8761, Z = -2.143 and p = .032) compared to the other children.

Role of training in sport-specific profiles

The first discriminant analysis served to discriminate between 81 highly active children who spent 5 hours or more per week in their sport. Four discriminant functions emerged (Wilks' Λ = .137 and p < .001) and an 85.2 % correct classification was found. Since none of the highly active children were involved in martial arts, only 5 groups of sports (Ball sports, Dance, Gymnastics, Racquet sports and Swimming) were included for this discriminant analysis. For the second and third discriminant analysis, which involved moderate and low active children, all six groups of sports were represented. The second discriminant analysis aimed to discriminate between 252 moderate active children who spend between 1 and 5 hours per week in one of the six groups of sports. Five discriminant functions emerged but were found to be non-significant (Wilks' Λ = .682 and p = .291). Only 48.8 % of the children were correctly classified into their primary sport. Finally, the third discriminant analysis served to discriminate between 184 low active children who spend 1 hour or less per week in one of the six groups of sports. The five discriminant functions that emerged were non-significant (Wilks' Λ = .577 and p = .230) and 48.4 % of the children were correctly classified. The results of the three different discriminant analyses are displayed in Figures 24, 25 and 26.

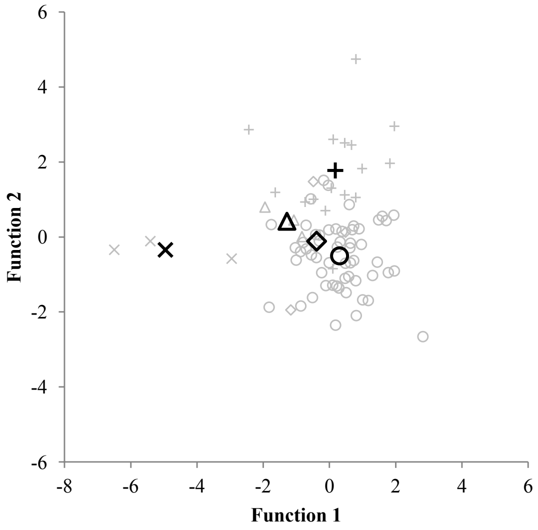


Figure 24: Discriminating between 81 children participating 5 hours or more per week in their sport.

Ball sports = ○ Dance = ◆ Gymnastics = + Racquet sports = Δ Swimming = ×

Functions at Group Centroids: Ball sports Function 1 = 0.305; Ball sports Function 2 = -0.506; Dance Function 1 = -0.389; Dance Function 2 = -0.114; Gymnastics Function 1 = 0.176: Gymnastics Function 2 = 1.773; Racquet sports Function 1 = -1.285; Racquet sports Function 2 = 0.418; Swimming Function 1 = -4.954; Swimming Function 2 = -0.344.

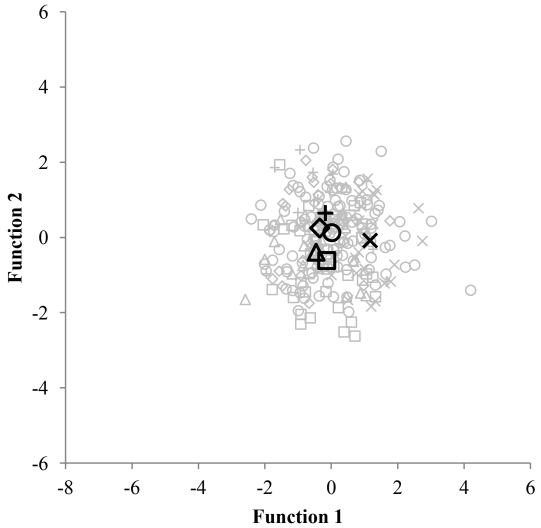


Figure 25: Discriminating between 252 children participating between 1 and 5 hours per week in their sport.

Ball sports = ○ Dance = ◆ Gymnastics = + Martial arts = □ Racquet sports = Δ Swimming = ×

DFunctions at Group Centroids: Ball sports Function 1 = 0.016; Ball sports Function 2 = 0.126; Dance Function 1 = -0.348; Dance Function 2 = 0.250; Gymnastics Function 1 = -0.177: Gymnastics Function 2 = 0.646: Martial arts Function 1 = -0.136; Martial arts Function 2 = -0.615; Racquet sports Function 1 = -0.457; Racquet sports Function 2 = -0.393; Swimming Function 1 = 1.170; Swimming Function 2 = -0.082.

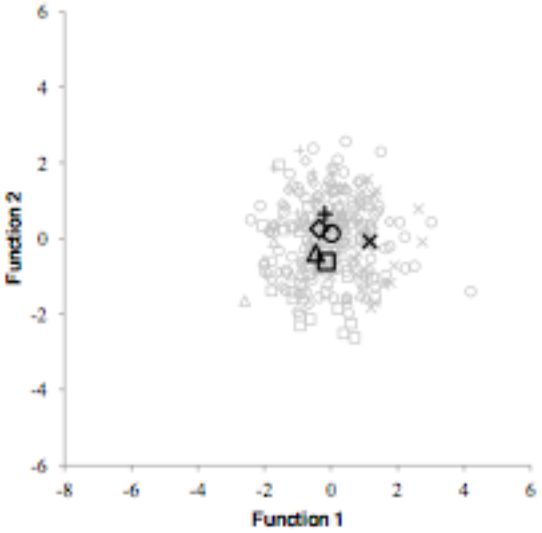


Figure 26: Discriminating between 184 children participating 1 hour or less per week in their sport.

Ball sports = ○ Dance = ◆ Gymnastics = + Martial arts = □ Racquet sports = Δ Swimming = ×

Functions at Group Centroids: Ball sports Function 1 = -0.556; Ball sports Function 2 = -0.441; Dance Function 1 = -0.169; Dance Function 2 = 0.000; Gymnastics Function 1 = -0.270: Gymnastics Function 2 = -0.240: Martial arts Function 1 = 1.384; Martial arts Function 2 = -0.881; Racquet sports Function 1 = -0.307; Racquet sports Function 2 = 0.254; Swimming Function 1 = 0.580; Swimming Function 2 = 0.475.

Role of training in PQ and MQ levels

The Shapiro-Wilk test showed that the variable ‘amount of hours per week’ was not normally distributed ($p < .001$). The Kruskal-Wallis test revealed a significant difference in the amount of hours per week spent in the primary sport between the three different groups ($\chi^2(2) = 8{,}315$ and $p = .016$). The children performing under average on PQ and MQ spent significantly fewer hours in sport (2.50 ± 1.84 hours per week) compared to the children performing best (3.25 ± 2.60 hours per week) ($U = 9640.5$, $Z = -2.406$ and $p = .016$) and the children performing above average (2.90 ± 1.96 hours per week) ($U = 18597$, $Z= -2.185$ and $p = .029$). Children scoring best on PQ and MQ did not significantly differ from the ‘above average group’ in terms of hours of sport per week ($U = 5699$, $Z = -.629$ and $p = .529$). In Fig. 4a, MQ is plotted against PQ in which the difference is made between the children from a high, moderate and low level of physical fitness and motor coordination. Figures 27b, 27c and 27d present the MQ/PQ plot for these three levels separately. A positive MQ/PQ equals a score above the average score of the group. Zero represents the average score of the group. A negative MQ/PQ equals a score under the average score of the group. Fig. 4b presents the PQ and MQ scores for the children performing best, i.e. a score of .5 or higher on both PQ and MQ. In Fig. 4c, PQ and MQ levels are shown for the children performing above average with a PQ and/or MQ between .0 and .5. Finally, Fig. 4d presents the PQ and MQ scores of the children performing under average with a PQ and/or MQ of .0 or lower.

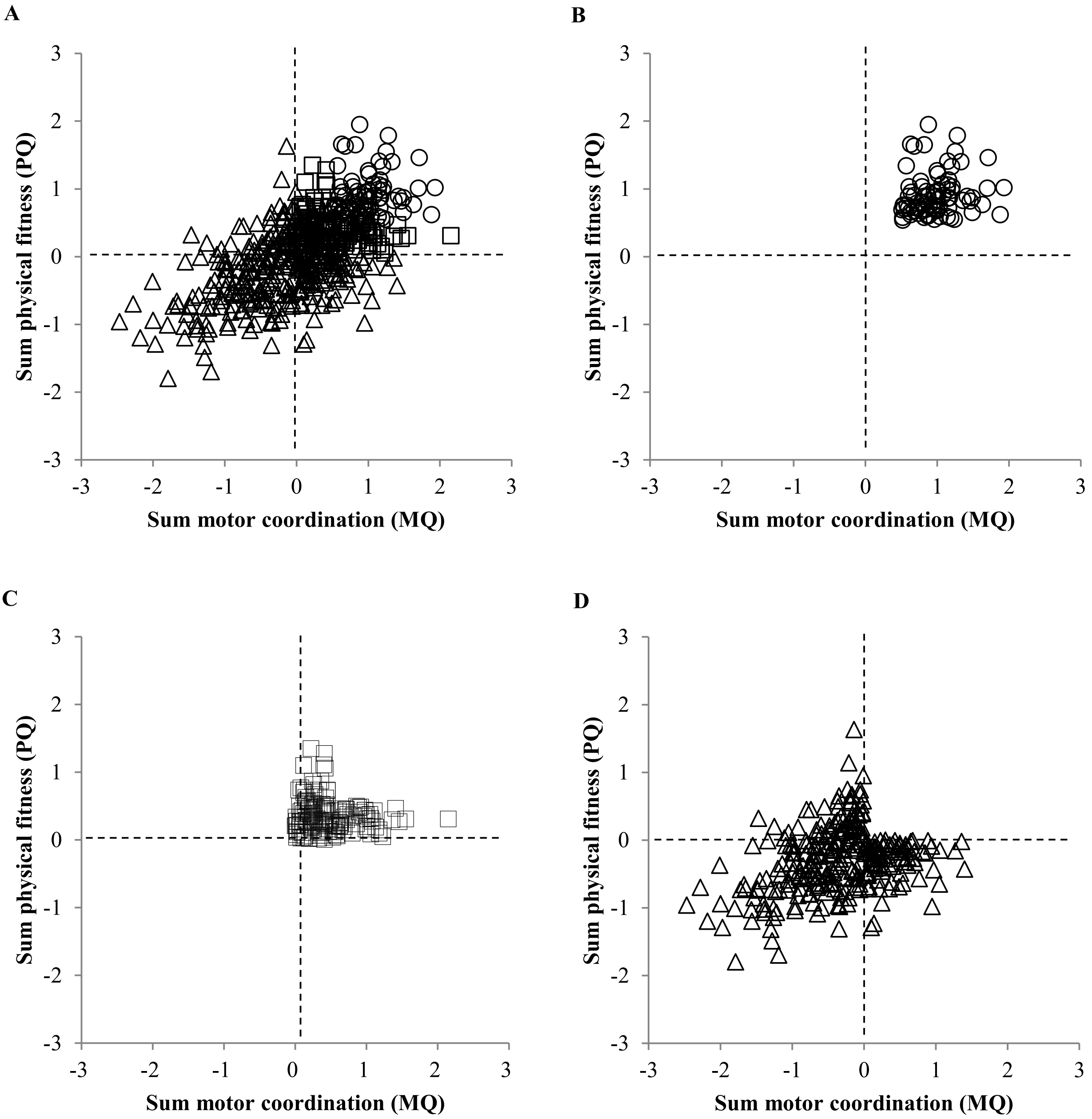


Figure 27: Scatterplot of physical fitness (PQ) and motor coordination (MQ).

A. Total sample, B. Children performing best, C. Children performing above average, D. Children performing under average.

Best performers = ○ (PQ and MQ > 0.5)
Above average performers = □ (PQ and MQ > 0 & PQ or MQ < 0.5)
Under average performers = Δ (PQ and/or MQ < 0)

Discussion

The main aim of this study was to examine whether 9 to 11 year old children already involved in sports participation demonstrate sport-specific characteristics in terms of anthropometry, physical fitness and motor coordination. The current study showed that in general, children at a young age do not present sport-specific physical characteristics except in children with a high training volume. Another result is that, regardless of the type of sport, children with the best physical fitness and motor coordination characteristics are the ones who train the most hours per week. The few differences between the six groups of sports included within this study (Ball sports, Dance, Gymnastics, Martial arts, Racquet sports and Swimming) comprised of the better jumping abilities of the gymnasts, the poorer flexibility of the racquet sport players and the poorer ball skills and the partly poorer gross motor coordination (only in terms of the moving sideways test) of the children involved in martial arts. These differences however, do not entirely correspond with the sport-specific profiles formed by extensive research. Adolescent and adult gymnasts are characterized by their flexibility, strength, coordination, jumping capabilities, anaerobic endurance and distinct anthropometric profile (17, 35, 36). Within this study, gymnasts only distinguished themselves with better jumping abilities. Literature regarding this topic is inconclusive. Bencke and colleagues (35) found that 11 year old gymnasts showed better jumping capabilities compared to swimmers, handball players and tennis players of the same age. Meanwhile, Pion and colleagues (19) found that male gymnasts with an average age of 16.1 ± 0.8 years displayed poorer jumping capabilities compared to non-gymnasts (including badminton, basketball, handball, judo, soccer, table tennis, triathlon and volleyball). When considering the racquet sport players, it must be noted that the larger part of the group (n = 46) played tennis (n = 42). Therefore, it is likely that the contribution of the badminton players was rather small. With this in mind, we could state that within this study, the tennis players are less flexible compared to the rest of the children, which however, could not be confirmed nor refuted by literature. Similarly, little is known about ball skills of children involved in martial arts which probably makes sense since combat sports have little to do with ball skills. Characteristics that do play an important role in martial arts are: flexibility, explosive strength, balance, agility and motor coordination (37). The latter one does not emerge as distinguishing feature within this study. On the contrary, the children involved in martial arts performed worse on one of the gross motor coordination tests (moving sideways) compared to the rest of the children. Regarding ball skills, it is remarkable that the ball sport players do not outperform the rest of the children, as one would expect considering that ball skills are central in ball sports. This however, does not say that much about the profile of 9 to 11 year old ball sport players but it does unveil a weakness about this specific test for this particular population. With scores between 8.00 and 9.02 (number of correct dribbles with a maximum of 10) (see Table 10), it is likely that the test was too easy for 9 to 11 year old children, which resulted in a ceiling effect, and makes it difficult to find a difference between ball sport players and non-ball sport players.

In the current study, 9 to 11 year old children did not present sport-specific physical characteristics, which could be explained by several reasons. First, the amount of hours spent in a sport may have influenced the physical profile of the children. Sport-specific characteristics are partly the result of what Ericsson (22) called the 10.000 hours rule. Hours and hours of deliberate practice are needed to develop expert performance. In contrast to elites, adolescent athletes who often dedicated years and years of training to their sport, the children within this study (9 to 11 years old) have not spent enough time yet within their sport to demonstrate sport specific characteristics. Adolescent athletes from different types of sports on the other hand, can clearly be distinguished based on their physical profile (18, 19), even when discriminating between sports within the same category. Pion and colleagues (37) found a 100% correct classification when discriminating between three different martial arts sports (judo, karate and tae kwon do) in highly trained U18 male athletes. The assumption that a more extended training history leads to more pronounced sport specific characteristics is supported by the results of the discriminant analyses. Indeed, the current study showed that in 85.2 % of the cases, the 81 high active children who spend 5 or more hours per week in their sport were correctly assigned to their proper sport based on their anthropometric, physical fitness and motor coordination profile. In contrast, when considering low active children who spend not more than 1 hour per week, less than half of the children (48.4 %) were correctly allocated. Second, it is possible that 9 to 11 year old children do not take into account their physical characteristics when choosing a type of sport. A review on children's motives for sports participation pointed out the influence of five motivational factors including perception of competence, fun and enjoyment, parents, learning new skills, and friends and peers (38). Fun and enjoyment is known to be one of the most important motives for children to participate in a sport (39-42). It is possible that children do not choose a sport that matches their physical qualities in the age range from 9 to 11 but they make that choice based on how much they enjoy the sport.

Regarding talent identification and development, these two viewpoints on exhibiting sport specific characteristics at a young age, can be associated with the nature versus nurture debate, one of the most discussed subjects within this area (43-45). Nature refers to the innate ability to excel within a sport while nurture means developing skills through an extended amount of high quality training (43). On the one hand, the difference in sport specific profiles between children who have benefited from a different amount of training hours as found within this study, can be associated with the concept of nurture. The more hours per week a child spends within the sport, the closer it gets to the 10.000 hours which results in exhibiting more pronounced sport specific characteristics. Moreover, an extended training history is not only associated with more pronounced sport specific characteristics; it is also related to better physical fitness and motor coordination qualities. Indeed, results indicated that the children with a better physical fitness and motor coordination profile spend more hours per week in their sport compared to the children who are not quite as strong physically and coordinative. This is supported by a study of Fransen and colleagues (10) who found a positive effect of the amount of training hours per week on the level of physical fitness and motor coordination in 10 to 12 year old boys. Boys who spent few hours per week (<4 hours) in their sport showed poorer motor coordination, flexibility and jumping capabilities compared to boys who spent many hours per week (>4 hours). At the other hand, the assumption that 9 to 11 year old children may not consider their personal characteristics when choosing a sport means that the advantage of an innate ability (nature) goes to waste. To optimize the process of talent identification, children should be supported in choosing a sport that matches their personal characteristics.

Both a genetic potential and optimal environmental factors are favorable to attain a high level of sports performance. However, until now it is not clear whether the nature-nurture debate applies to a broader level of sports participation. The current study elucidated that when children spend a sufficient amount of hours in a sport, they exhibit some sport specific characteristics. It however remains unknown to what degree the children in this particular population chose a sport that matches their personal characteristics. It is possible that the children chose a sport for a different reason (e.g. environmental factors like parental influence) and they exhibit a sport specific profile as a result of many training hours. Meanwhile, there might be another sport that fits better with their anthropometric, physical fitness and motor coordination profile. Future studies should investigate (1) to what extent children need to choose a sport that matches their personal characteristics and (2) whether this well considered choice is better than a choice based on environmental factors like parental influence to protect them from early dropout. In addition, it should be investigated (3) to what degree environmental factors like training volume have an influence on the match between the child and the sport. Furthermore, assuming that a match between the child and the sport is preferable, the question remains whether the elite sport specific profiles apply for 9 to 11 year old children.

One of the strengths of the present study is the large sample size, which made it possible to explore a large number of sports. In addition, unlike many other studies, the focus was on the anthropometric, physical fitness and motor coordination characteristics of children participating in a wide range of sports regardless of their level of sports participation. Despite the large sample size, some sports were not well represented. Therefore, the authors chose to combine sports based on common characteristics. From the viewpoint of talent identification and development it is favorable to focus on an individual sport, rather than on groups of sports.

Acknowledgements

The authors would like to thank Barbara Vandorpe and Joric Vandendriessche for their contribution to the data collection for this manuscript.

References

1. Barnett LM, Van Beurden E, Morgan PJ, Brooks LO, Beard JR. Childhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity. J Adolescent Health. 2009;44(3):252-259.
2. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000-2003. J Sci Med Sport. 2004;7(1 Suppl):6-19.
3. Fransen J, Deprez D, Pion J, Tallir IB, D'Hondt E, Vaeyens R, et al., Changes in Physical Fitness and Sports Participation Among Children With Different Levels of Motor Competence: A 2-Year Longitudinal Study. Pediatr Exerc Sci. 2014;26(1):11-21.
4. Gentier I, D'Hondt E, Shultz S, Deforche B, Augustijn M, Hoorne S, et al., Fine and gross motor skills differ between healthy-weight and obese children. Res Dev Disabil. 2013;34(11):4043-4051.
5. Ortega FB, Ruiz JR, Castillo MJ, Sjostrom M. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obesity. 2008;32(1):1-11.
6. Sallis JF, Patrick K. Physical activity guidelines for adolescents: consensus statement. Pediatr Exerc Sci. 1994;6(4):302-314.
7. Fisher A, Reilly JJ, Kelly LA, Montgomery C, Williamson A, Paton JY, et al., Fundamental movement skills and habitual physical activity in young children. Med Sci Sport Exer. 2005;37(4):684-688.
8. Hands B. Changes in motor skill and fitness measures among children with high and low motor competence: A five-year longitudinal study. J Sci Med Sport. 2008;11(2):155-162.
9. Okely AD, Booth ML, Patterson JW. Relationship of physical activity to fundamental movement skills among adolescents. Med Sci Sport Exer. 2001;33(11):1899-1904.
10. Fransen J, Pion J, Vandendriessche J, Vandorpe B, Vaeyens R, Lenoir M, et al. Differences in physical fitness and gross motor coordination in boys aged 6-12 years specializing in one versus sampling more than one sport. J Sport Sci. 2012;30(4):379-386.
11. Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. J Athl Training. 2007;42(1):42-46.
12. Duncan MJ, Woodfield L, al-Nakeeb Y. Anthropometric and physiological characteristics of junior elite volleyball players. Brit J Sport Med. 2006;40(7):649-951.
13. Elferink-Gemser MT, Visscher C, Lemmink KAPM, Mulder T. Multidimensional performance characteristics and standard of performance in talented youth field hockey players: A longitudinal study. J Sport Sci. 2007;25(4):481-489.
14. Kirkpatrick J, Comfort P. Strength, Power, and Speed Qualities in English Junior Elite Rugby League Players. J Strength Cond Res. 2013;27(9):2414-2419.
15. Reilly T, Bangsbo J, Franks A. Anthropometric and physiological predispositions for elite soccer. J Sport Sci. 2000;18(9):669-683.
16. Russell M, Tooley E. Anthropometric and performance characteristics of young male soccer players competing in the UK. Serbian journal of sports sciences. 2011;5(4):155-162.
17. Vandorpe B, Vandendriessche J, Vaeyens R, Pion J, Lefevre J, Philippaerts R, et al., Factors Discriminating Gymnasts by Competitive Level. Int J Sports Med. 2011;32(8):591-597.
18. Leone M, Lariviere G, Comtois AS. Discriminant analysis of anthropometric and biomotor variables among elite adolescent female athletes in four sports. J Sport Sci. 2002;20(6):443-449.
19. Johan Pion, Veerle Segers, Job Fransen, Gijs Debuyck, Dieter Deprez, Leen Haerens, Roel Vaeyens, Renaat Philippaerts, Matthieu Lenoir. Generic anthropometric and performance characteristics among elite adolescent boys in nine different sports. (2014). European Journal of Sport Science, Ahead of print, DOI: 10.1080/17461391.2014.944875
20. Côté J, Hancock DJ. Evidence-based policies for youth sport programmes International Journal of Sport Policy and Politics 2014;6(3):In press.
21. Côté J, Lidor R, Hackfort D. ISSP Position Stand: To sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. International Journal of Sport and Exercise Psychology. 2009;9:7-17.
22. Ericsson KA, Krampe RT, Teschromer C. The Role of Deliberate Practice in the Acquisition of Expert Performance. Psychological Review. 1993;100(3):363-406.

23. Vandorpe B, Vandendriessche J, Vaeyens R, Pion J, Matthys S, Lefevre J, et al., Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach. J Sci Med Sport. 2012;15(3):220-225.
24. Matthys SP, Vaeyens R, Fransen J, Deprez D, Pion J, Vandendriessche J, et al., A longitudinal study of multidimensional performance characteristics related to physical capacities in youth handball. J Sports Sci. 2013;31(3):325-334.
25. Vandendriessche JB, Vandorpe BFR, Vaeyens R, Malina RM, Lefevre J, Lenoir M, et al., Variation in Sport Participation, Fitness and Motor Coordination With Socioeconomic Status Among Flemish Children. Pediatr Exerc Sci. 2012;24(1):113-128.
26. Council of Europe. Committee for the Development of Sport. EUROFIT: Handbook for the EUROFIT tests of physical fitness. Rome: Secretariat of the Committee for the Development of Sport within the Council of Europe; 1988
27. Vrijkotte S, De Vries S, Jongert T. Fitheidstesten voor de jeugd. Leiden: TNO Kwaliteit van Leven; 2007.
28. Fetz F, Kornexl E. Sportmotorische Tests. Berlin: Bartels & Wernitz; 1993.
29. Johnson BL, Nelson JK. Practical measurements for evaluation in physical education. 4th ed. Edina: Minneapolis: Burgess Publishing Company; 1986.
30. Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and counter movement jump tests. J Strength Cond Res. 2004;18(3):551-555.
31. Cometti G, Cometti D. La pliométrie: Méthodes, entraînements et exercices. Paris: Chiron; 2007.
32. Bruininks RH, Bruininks BD. BOT-2: Bruininks-Oseretsky Tests of Motor Proficiency. Minneapolis: AGS Publishing; 2006.
33. Kiphard EJ, Schilling F. Körperkoordinationstest für Kinder 2. Überarbeitete und ergänzte Auflage. Weinheim: Beltz: Test GmbH. 2007.
34. Philippaerts RM, Matton L, Wijndaele K, Balduck AL, De Bourdeaudhuij I, Lefevre J. Validity of a physical activity computer questionnaire in 12-to 18-year-old boys and girls. Int J Sports Med. 2006;27(2):131-136.
35. Bencke J, Damsgaard R, Saekmose A, Jorgensen P, Jorgensen K, Klausen K. Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming. Scand J Med Sci Spor. 2002;12(3):171-178.
36. Carrick FR, Oggero E, Pagnacco G, Brock JB, Arikan T. Posturographic testing and motor learning predictability in gymnasts. Disabil Rehabil. 2007;29(24):1881-9.
37. Pion JF, J.; Lenoir, M.; Segers, V. The value of non-sport-specific characteristics for talent orientation in young male judo, karate and taekwondo athletes. Arch Budo. 2014;10:147-154.
38. Cope EJ, Bailey R, Pearce G. Why do children take part in, and remain involved in sport? A literature review and discussion of implications for sports coaches. International Journal of Coaching Science. 2013;7(1):55-74.
39. Chalip L, Green BL. Establishing and maintaining a modified youth sport program: Lessons from Hotellings location game. Sociology of Sport Journal 1998;15(4):326-42.
40. Green BC. Building sport programs to optimize athlete recruitment, retention, and transition: Toward a normative theory of sport development. J Sport Manage. 2005;19(3):233-253.
41. Wankel LM, Kreisel PSJ. Factors Underlying Enjoyment of Youth Sports - Sport and Age Group Comparisons. J Sport Psychol. 1985;7(1):51-64.
42. Weiss MR, Amorose AJ. Motivational orientations and sport behaviour. In: Horn TS, editor. Advances in Sport Psychology. 3 ed. Champaign, IL: Human Kinetics; 2008. p. 115-155.
43. Davids K, Baker J. Genes, environment and sport performance: why the nature-nurture dualism is no longer relevant. Sports medicine. 2007;37(11):961-80.
44. Durand-Bush N, Salmela JH. The Development of Talent in Sport. In: Singer RNH, H. A.; Janelle, C. M., editor. Handbook of Sport Psychology 2ed. Canada: John Wiley & Sons; 2001. p. 269-289.
45. Tucker R, Collins M. What makes champions? A review of the relative contribution of genes and training to sporting success. Br J Sports Med. 2012;46(8):555-561.

In mijn hoofd had ik dat record al gebroken

Ik moest het alleen nog zwemmen

(Fred De Burghgraeve)

2.2 TALENT ORIENTATION

2.2.1 PAPER 2: GENERIC ANTHROPOMETRIC AND PERFORMANCE CHARACTERISTICS AMONG ELITE ADOLESCENT BOYS IN NINE DIFFERENT SPORTS

Johan Pion, Veerle Segers, Job Fransen, Gijs Debuyck, Dieter Deprez,

Leen Haerens, Roel Vaeyens, Renaat Philippaerts and Matthieu Lenoir

European Journal of Sport Science,

2015

15(5), p 357-366

Abstract

Background

The aim of the present study was to evaluate the Flemish Sports Compass, a non-sport specific generic testing battery. It was hypothesized that the set of 22 tests would have sufficient discriminant power to allocate athletes to their own sport based on a unique combination of test scores.

Methods

First, discriminant analyses were applied to 22 tests of anthropometry, physical fitness and motor coordination in 141 boys under 18 (16.1 ± 0.8 years) and post age at peak height velocity (maturity offset = 2,674 ± 0,926) from Flemish elite sport schools for badminton, basketball, gymnastics, handball, judo, soccer, table tennis, triathlon and volleyball. Second, nine sequential discriminant analyses were used to assess the ability of a set of relevant performance characteristics classifying participants and non-participant for the respective sports.

Principal Findings

Discriminant analyses resulted in a 96,4% correct classification of all participants for the nine different sports. When focusing on relevant performance characteristics, 80.1% to 97.2% of the total test sample was classified correctly within their respective disciplines. The discriminating characteristics were briefly the following: flexibility in gymnastics, explosive lower limb strength in badminton and volleyball, speed and agility in badminton, judo, soccer and volleyball, upper body strength in badminton, basketball and gymnastics, cardio-respiratory endurance in triathletes, dribbling skills in handball, basketball and soccer and overhead throwing skills in badminton and volleyball.

Conclusions

The generic talent characteristics of the Flemish Sports Compass enable the distinction of adolescent boys according to their particular sport. Implications for talent programs are discussed.

Introduction

In the last decades, scientific evidence that facilitates the search for young talented athletes has attracted the interest of policy makers. Seeking to optimise the efficiency of the sports development pathway is critical for less populous countries that wish to maximise their chances in international competition (De Bosscher, Bingham et al., 2008). Sporting federations allocate scarce resources towards the optimisation of talent identification programs. Therefore, providing consulting services to schools and sports clubs regarding the development of talented athletes is a practical challenge. Talent refers to a successful outcome of domain-specific performance (Van Rossum and Gagné 2005), in casu sports. To attain the highest standards within a particular sport, athletes rely on a combination of natural abilities (nature) and well-developed performance determinants (nurture). Understanding the characteristics that might predict future performance is crucial to gain insight in how talented individuals are detected or identified and how talent might be transferred to different domains. In order to do so, research groups have collected an extensive amount of performance characteristics of children, adolescents and senior athletes (Régnier, Salmela et al., 1993, Hoare and Warr 2000, Williams and Reilly 2000, Abbott and Collins 2002, Vaeyens, Lenoir et al., 2008, Bullock, Gulbin et al., 2009, Mohamed, Vaeyens et al., 2009, Matthys, Vaeyens et al., 2011, Fransen, Pion et al., 2012, Matthys, Vaeyens et al., 2012, Vandendriessche, Vaeyens et al., 2012, Vandorpe, Vandendriessche et al., 2012, Matthys, Vaeyens et al., 2013). This seems slightly one-dimensional by focusing on performance aspects, but the classic subdivision into morphological, physical and motor talent characteristics already provides a broad basis for talent detection and identification.

Knowing which athletes from different sports share similar physical characteristics provide talent programs with valuable information when directing young children towards sports that optimally suit their specific, individual characteristics. One of the reasons why this talent orientation has not been implemented in the past is the overabundance of physical and motor tests that prevent a clear picture of transfer possibilities between sports. While most studies do evaluate similar performance characteristics such as speed, strength and agility, the direct comparison between for example a basketball player's 20 m sprint time and a soccer player's 30m sprint time or between specific agility tests for volleyball (Gabbett and Georgieff 2007) and agility tests for gymnastics (Vandorpe, Vandendriessche et al., 2012) could be problematic Although these tests measure more or less the same characteristic (e.g. speed, agility), using different test setups does not allow for a between sports comparison. In contrast, for anthropometrical measurements, the same test protocols have been used throughout research for stature, body mass, BMI, etc., making comparisons between athletes and between sports easier (Leone and Lariviere 1998, Leone, Lariviere et al., 2002).

Because of the lack of uniformity in tests used to assess physical performance across studies and between sports, there is a need for a broad generic test battery, which will in turn accentuate the differences between sports. The general aim of this study is to discriminate elite adolescent boys, using a test battery that uses non sport-specific tasks into the sport that best suits their specific anthropometric, physical and motor coordination profile. Therefore, this research investigated whether the test items used in the Flemish Sports Compass (FSC) are able to differentiate participants from Flemish elite sport schools in nine sports i.e. badminton, basketball, gymnastics, handball, judo, soccer, table tennis, triathlon and volleyball. It is hypothesized that the set of 22 tests in the FSC will have sufficient discriminant power to allocate athletes to their own sport based on a unique combination of test scores.

Methods

Participants and study design

A sample of 141 young elite male athletes U18 (16.1 ± 0.8 years) post age at peak height velocity (maturity offset = 2.7 ± 0.9 years) participated in the present study. All participants had been selected by their sports federations for the Flemish elite sport schools. Only athletes that represented Belgium in competition at international level were included in this study. They competed in one of the following nine sports: badminton (n=12), basketball (n=27), gymnastics (n=8), handball (n=28), judo (n=8), soccer (n=20), table tennis (n= 6), triathlon (n= 12) and volleyball (n=20). This study is in accordance with recognized ethical standards and was approved by the local Ethics Committee of the Ghent University Hospital. Written informed parental consent was obtained from all participants.

Measurements

The participants completed the 22 generic tests of the FSC, consisting of anthropometrical, physical performance and motor coordination measurements, assessed by 11 experienced examiners. At any given time, instruction and demonstration were standardized according to the test guidelines. All tests were conducted on the same indoor venue, on the preferred day for nine respective “Flemish elite sport schools”. The tests started at 10 a.m. and the athletes were instructed to refrain from strenuous exercise for at least one day before the test sessions. All tests were performed barefoot with the exception of the sprints, the counter movement jump and the endurance shuttle run test, which were all performed with running shoes.

Anthropometry

Height (0.1 cm, Harpenden, portable Stadiometer, Holtain, UK), sitting height (0.1 cm, Harpenden, sitting table, Holtain, UK), and body weight and body fat percentage (0.1 kg, Tanita, BC-420SMA) were assessed according to previously described procedures (Lohman, Roche et al., 1988) and manufacturer guidelines. Leg length was calculated as the difference between height and sitting height. In order to estimate the maturity status of the participants, a non-invasive technique based upon chronological age (decimal age) and anthropometrical variables was used (Mirwald, Baxter-Jones et al., 2002). Although it was recently shown that predicted APHV for late and early maturing boys can be inaccurate, Malina and Koziel underline that the utility of this non-invasive technique in talent programs is not problematic (Malina & Koziel, 2014). The biological maturation index predicts years from peak height velocity (PHV) as a measure of maturity offset.

Subsequently, age at peak height velocity (APHV) was calculated by subtracting predicted years from PHV, from the chronological age.

Physical Performance

Hamstring and lower back flexibility was assessed by the sit-and-reach test of the European Test of Physical fitness (EUROFIT) (Council of Europe 1988). The shoulder rotation test was used to evaluate shoulder flexibility (Matthys, Vaeyens et al., 2013) with an accuracy of 0.5 cm. To assess explosive leg power, counter movement jump and standing broad jump were performed. The participants performed three single counter movement jumps without arm swing recorded with an OptoJump device (MicroGate, Italy). The highest of three jumps was used for further analysis (0.1 cm). The standing broad jump is part of the EUROFIT and was measured with an accuracy of 1.0 cm (Council of Europe 1988). Speed and agility were assessed by a 10 x 5 m shuttle run test (Council of Europe 1988) and two maximal sprints of 30 m with split times at 5 m and 30 m. The recovery time between each sprint was set at 2 min. The fastest time needed to cover distances was used for analysis (Matthys, Vaeyens et al., 2013). The shuttle run and sprint test were recorded with MicroGate Racetime2 chronometry and Polifemo Light photocells at an accuracy of 0.001 s (MicroGate, Italy). Upper body strength endurance was measured by a knee push-ups and sit-ups test, according to the Bruininks-Oseretzky Test of Motor Proficiency (BOT-2) procedures (Bruininks and Bruininks 2006), requiring the athletes to execute as many repetitions as possible in 30 seconds. Finally, the cardiorespiratory endurance was measured using the endurance shuttle run test with an accuracy of 0.5 min (Council of Europe 1988).

Motor Coordination

Gross motor coordination was evaluated by means of three subtests of the "KörperkoordinationsTest für Kinder" (KTK) (Kiphard and Schilling 2007), (1) Backward Balance: walking backwards along balance beams of decreasing width (6 cm; 4.5 cm and 3 cm respectively); (2) Jumping Sideways: Two-legged jumping sideways over a wooden slat (2 x 15 s), summing the number of jumps over the two trials; (3) Moving Sideways: Moving sideways on wooden platforms (2 x 20 s), summing the number of relocations over two trials. To assess dribbling performance, the UGent Dribbling Test (Mohamed, Vaeyens et al., 2009) was used. This test consists of three maximal dribble sprints of 18.33 m. The first trial was performed without a ball while the second and third trials were performed while dribbling a ball with hands and feet respectively. The dribbling protocols were identical for each execution. The recovery time between the 3 trials was set at 2 min. Time (accurately to 0.1s) was measured using a stopwatch. Furthermore, an overhead-throwing test with an official badminton shuttle was used in order to evaluate overarm throwing skill. The goal of this test was to throw the shuttle as far and accurate (straight forward) as possible, holding the shuttle between thumb and index. Throwing distance of five trials was used for further analysis (Mohamed, 2009).

Statistical analysis

All data were analysed using SPPS for windows version 19.0 and minimal statistical significance was set at ($p<0.05$). First, a discriminant analysis was used to investigate relevant physical performance measures in badminton, basketball, gymnastics, handball, judo, soccer, table tennis, triathlon and volleyball. In this analysis, belonging to either of nine different sports was the grouping variable and the independent variables were the test results obtained from the FSC i.e. five anthropometrical, ten physical and seven motor coordination characteristics. This discriminant analysis yielded nine Fisher's linear discriminant functions, one for every sport and eight different standardized canonical discriminant functions, one for each degree of freedom (n-1). Second, to understand which talent characteristics specifically discriminate between those who do and those who do not participate in a particular sport, three separate stepwise discriminant analysis for anthropometry, physical fitness and motor coordination were used. To do so, whether or not one participates in a given sport is the grouping variable and again, the test results obtained from FSC were the independent variables. Finally, to assess the multi-dimensional (anthropometry, physical fitness and motor coordination) set of talent characteristics that discriminate between athletes participating or not participating in a given sports discipline at the "Flemish elite sport schools", a sequential discriminant analysis was used. In this analysis the relevant talent characteristics (i.e. better test scores for respective participants versus non-participants) obtained from the previous stepwise discriminant analysis were entered as independent variables. The classification results indicate the correctly and not correctly classified athletes. Athletes classified as participant even though they are not participating the sport are classified false positive and the non-participants classified as participant are classified false negative.

Results

Discriminating between sports

The first analysis aimed at discriminating between nine different sports showed that none of the 141 cases were withheld and there was a 96,4% correct classification rate. There were three false positive and two false negative cases, of which one badminton player, one basketball and one soccer player were classified as a handball player and two handball players were classified as soccer players respectively (Table 11).

Table 11: Cases correctly classified in nine different sports according to the Flemish Sports Compass.

	Badminton	Basketball	Gymnastics	Handball	Judo	Soccer	Table tennis	Triathlon	Volleyball
Badminton	91,7%			8,3% (n=1)					
Basketball		96,3%		3,7% (n=1)					
Gymnastics			100%						
Handball				92,6%		7,4% (n=2)			
Judo					100%				
Soccer				5% (n=1)		95%			
Table tennis							100%		
Triathlon								100%	
Volleyball									100%

Fisher’s linear discriminant functions obtained from this first discriminant analysis reflect the relative importance of the FSC tests in discriminating between the nine sports. Since the grouping variable distinguishes between nine groups, eight canonical discriminant functions were required and generated. The Eigenvalues describes how much of the variance in the dependent variable is accounted for each of the functions. The first function accounts for 34,4% explained by the model. Discriminant function 1 and discriminant function 2 discriminate between each sport in terms of its profile, using the group centroids (e.g. 61,8%). The cumulative effect of eight functions accounts for 100% of cases classified correctly within sports. Hence the model can be used for predictive purposes.

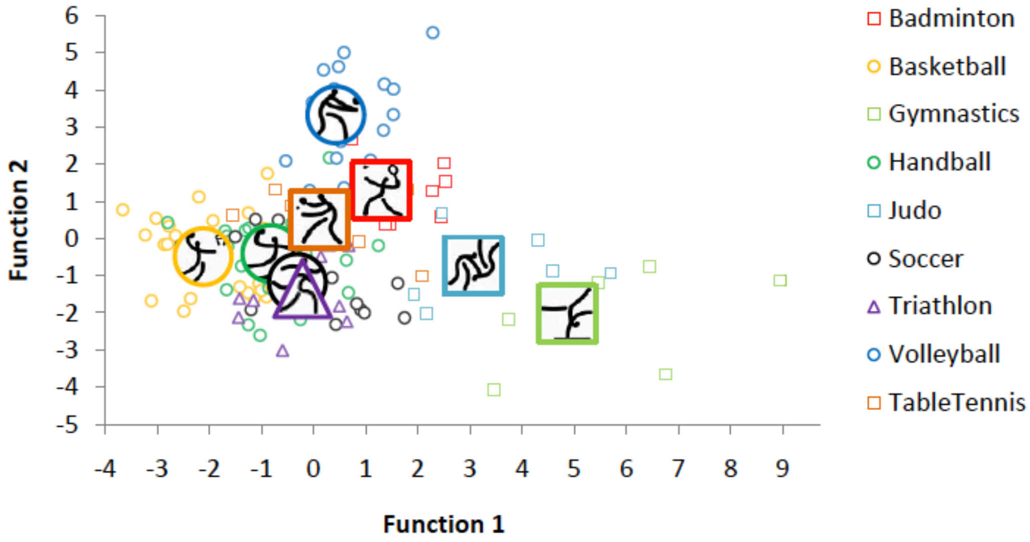


Figure 28: Differences based on canonical discriminant functions calculated from the 22 generic tests (FSC).

Note 1: The scatterplot has the canonical discriminant function coefficients as its axes, with Function 1 on the X and function 2 on the Y-axes. The nine groups cluster within the 2-dimensional space, indicating that the functions discriminate clearly between the nine sports. The first function on the X-axis was the most helpful in distinguishing between sports where dribbling is necessary. The centroids, which are the mean discriminant score for each group, are indicated by a pictogram.

Note 2: Functions at Group Centroids: Badminton Function 1 = 1.299; Function 2 = 1.309; Basketball Function 1 = -2.177; Function 2 = -0.480; Gymnastics Function 1 = 4,866; Function 2 = -2,021; Handball Function 1 = -0.823; Function 2 = -0.399; Judo Function 1 = 3.061; Function 2 = -0.728; Soccer Function 1 = -0.315; Function 2 = -1.179; Table tennis Function 1 = 0.110; Function 2 = 0.510; Triathlon Function 1 = -0.213; Function 2 = -1.349; Volleyball Function 1 = 0.428; Function 2 = 3.337

Identifying relevant talent characteristic for each sport.

Descriptive statistics for all variables used in each of three stepwise discriminant analyses can be found in Table 12

Table 12: Table 2: Anthropometrical, physical and motor talent characteristics for nine sports

	Badminton	Basketball	Gymnastics	Handball	Judo	Soccer	Table tennis	Triathlon	Volleyball
	n = 12	n = 27	n = 8	n = 27	n = 8	n = 20	n = 6	n = 6	n = 20
Age	16.656 ± 0.924	16.360 ± 0.900	16.874 ± 0.688	16.408 ± 0.843	16.867 ± 0.907	16.539 ± 0.823	16.754 ± 0.782	17.153 ± 0.518	16.636 ± 0.797
Anthropometrical characteristics									
Height (H) (cm)	175.2 ± 7.1	188.1 ± 8.4 *	167.5 ± 8.6 *	180.3 ± 6.0	169.3 ± 6.6*	176.2 ± 10.5 *	180.4 ± 6.4	176.1 ± 5.6	189.8 ± 4.3
Sitting Height (SH) (cm)	92.6 ± 3.7	95.8 ± 4.6 *	87.9 ± 4.8	93.8 ± 3.5	89.8 ± 4.3*	92.1 ± 4.8	94.8 ± 2.4	92.0 ± 4.3	98.4 ± 2.5
Weight (BW) (kg)	63.4 ± 7.6	74.9 ± 11.3	56.6 ± 8	69.4 ± 8.1	63.4 ± 7.4	64.9 ± 9.9	66.4 ± 7.0	62.3 ± 8.3	78.1 ± 7.6 *
Body Fat (BF) (%)	10.9 ± 3.9	10.3 ± 3.2	10.6 ± 1.7	11.1 ± 2.7	11.9 ± 2.4	10.4 ± 2.3	9.7 ± 2.1	8.6 ± 2.9 *	10.8 ± 2.6
BMI	20.6 ± 2.1	21.1 ± 2.5	20.1 ± 1.2	21.3 ± 1.7	22.1 ± 1.7 *	20.8 ± 1.5	20.4 ± 2.0	20.0 ± 1.9	21.7 ± 1.9
Physical characteristics									
Sit and reach (SAR) (cm)	29.0 ± 4.7	22.5 ± 8.7	40.5 ± 4 *	26.5 ± 7.5	32.0 ± 9.0	25.5 ± 6.5	31.0 ± 7.5	27.0 ± 9.5	29.0 ± 7.0
Shoulder rotation (SHoRo) (cm)	92.0 ± 14.5	118.0 ± 20.0	58.0 ± 23.5 *	110.5 ± 18.0	101.5 ± 8.5	90.5 ± 26.0	79.5 ± 29.5	93.5 ± 19.5	91.4 ± 22.0
Sprint 5m (S5) (s)	1.046 ± 0.066 *	1.099 ± 0.073	1.073 ± 0.060	1.094 ± 0.074	1.128 ± 0.054	1.092 ± 0.070	1.104 ± 0.038	1.188 ± 0.094	1.080 ± 0.091
Sprint 30m (S30) (s)	4.358 ± 0.182	4.402 ± 0.203	4.420 ± 0.201	4.426 ± 0.179	4.458 ± 0.143	4.356 ± 0.180 *	4.436 ± 0.220	4.662 ± 0.150	4.389 ± 0.216 *
Shuttle run (SHR) (s)	17.634 ± 0.604	18.233 ± 0.994	17.816 ± 1.060	17.953 ± 0.786	17.099 ± 0.580 *	17.753 ± 0.575	17.606 ± 0.615	18.594 ± 0.567	17.370 ± 0.930 *
Sit Ups (SUP) (n)	41 ± 6	46 ± 9 *	46 ± 6	43 ± 7	45 ± 3	37 ± 5	44 ± 3	38 ± 6	48 ± 6
Knee Push Ups (KPU) (n)	43 ± 7 *	38 ± 6	46 ± 8 *	38 ± 6	41 ± 3	39 ± 5	39 ± 3	38 ± 5	37 ± 4
Counter movement jump (CMJ) (cm)	40.5 ± 3.3 *	36.6 ± 4.9	36.3 ± 6.9	36.7 ± 4.5	36.1 ± 4.4	35.5 ± 4.3	38.5 ± 6.8	31.2 ± 3.1	45.5 ± 5.0 *
Standing broad jump (SBJ) (cm)	227 ± 18	232 ± 20	242 ± 16	221 ± 21	239 ± 15	226 ± 19	245 ± 22	209 ± 15	255 ± 16 *
Endurance shuttle run (ESR) (min)	12.0 ± 1.5	12.0 ± 1.5	9.0 ± 2.5	11.5 ± 1.0	11.5 ± 1.0	12.0 ± 1.5	13.0 ± 2.0	14.0 ± 1.0 *	12.0 ± 1.0
Motor characteristics									
Dynamic balance (KTKBB) (n)	62 ± 9	55 ± 13	68 ± 7	62 ± 9	67 ± 5 *	60 ± 11	56 ± 14*	65 ± 5	60 ± 12
Jumping sideways (KTKJS) (n)	105 ± 9	98 ± 12	107 ± 10	95 ± 11	101 ± 6 *	102 ± 12	107 ± 9 *	95 ± 10	96 ± 9
Moving sideways (KTKMS) (n)	71 ± 6	64 ± 13	74 ± 4	64 ± 7	73 ± 10	67 ± 9	77 ± 12	70 ± 10	65 ± 10
Dribble run (SR) (s)	11.8 ± 0.7	11.5 ± 1.0	11.1 ± 0.9*	11.6 ± 0.7	12.6 ± 0.7	11.2 ± 0.7	11.5 ± 0.8	11.7 ± 1.0	11.7 ± 0.8
Dribble hands (SRH) (s)	15.4 ± 1.9	12.8 ± 1.1 *	18.5 ± 5.0	13.5 ± 1.1 *	18.3 ± 2.0	14.1 ± 1.5	13.9 ± 0.5	15.8 ± 1.9	14.9 ± 1.3
Dribble feet (SRF) (s)	22.8 ± 3.0	25.7 ± 2.9	28.1 ± 5.3	25.2 ± 4.4	29.0 ± 5.7	19.0 ± 1.5 *	23.5 ± 5.9	24.4 ± 2.9	26.6 ± 4.6
Throwing distance (TDIS) (m)	38.8 ± 2.2 *	31.2 ± 2.3	33.2 ± 4.1	33.3 ± 3.8	31.4 ± 2.4	33.7 ± 2.7	33.6 ± 2.7	32.4 ± 3.6	36.6 ± 2.5 *

Data are means ± standard deviation
* Stepwise discriminant analysis with significant F-value

Badminton

A first stepwise discriminant analysis showed that there were no measures of anthropometry that discriminated badminton players from the rest of the test sample. For physical fitness, knee push-up (F =6.041 and P =0.015), sprint 5m (F =5.535 and P =0.005), counter movement jump tests (F =5.262 and P =0.002) and standing broad jump (F =5.498 and P <0.001) discriminated between badminton and non-badminton players. Better scores for knee push-up, sprint 5m and counter movement jump tests and lower scores for standing broad jump were observed in Badminton players than in the rest of the test sample. Throwing distance (F =31.536 and P <0.001) and dribble run (F =19.579 and P <0.001) were the discriminating motor tests, where badminton players had better scores for throwing distance and lower scores for dribble run.

Basketball

It was shown that basketball players were generally taller (F =23.387 and P <0.001) and had a higher sitting height (F =19.992 and P <0.001). For physical fitness, better scores for sit-ups (F =12.782 and P <0.001) and lower scores for shoulder rotation (F =23.823 and p <0.001) and sit and reach (F =15.682 and P <0.001) discriminated between basketball players and non-basketball players. Better scores for dribble hands (F =21.368 and P <0.001) and lower scores for throwing distance (F =25.286 and P <0.001), dribble feet (F =19.203 and P <0.001) and backwards balance (F =15.875 and P <0.001) were the discriminating motor coordination tests.

Gymnastics

A stepwise discriminant analysis showed that gymnasts were generally smaller (F =15.881 and P <0.001). For physical fitness, better scores for sit and reach (F =22.059 and P <0.001), shoulder rotation (F =37.583 and P <0.001), knee push-ups (F =27.980 and P <0.001) and lower scores for endurance shuttle run (F =36.032 and P <0.001) and counter movement jumps (F =24.633 and P <0.001) discriminated between gymnasts and non-gymnasts. Better scores for dribble run and lower scores dribble hands were the discriminating motor coordination tests.

Handball

There where no measures of anthropometry that discriminated handball players from the rest of the test sample. Lower scores for shoulder rotation (F =7.703 and P =0.006) and standing broad jump (F =6.385 and P =0.002) discriminated between handball and non-handball players. Better scores for dribble hands (F =6.717 and P =0.011) and lower scores for jumping sideways (F =6.358 and P =0.002) were the discriminating motor coordination tests.

Judo

A stepwise discriminant analysis showed that judo athletes were smaller (F =11.343 and P =0.001), had a lower body weight (F =2.129 and P =0.147) and a higher body mass index (F =2.586 and P =0.110). For physical fitness, better scores for shuttle run (F =6.598 and P =0.011) and lower scores for counter movement jump (F =5.466 and P =0.005) discriminated between judo athletes and non-judo athletes. Better scores for dribble hands smaller (F =23.645 and P =0.001) was the only motor coordination test.

Soccer

Soccer players were smaller than the rest (F =4.261 and P =0.041). For physical fitness, better scores for sprint 30m (F =11.465 and P <0.001) and lower scores for sit-ups (F =17.297 and P <0.001) and counter movement jumps (F =9.696 and P <0.001) discriminated between soccer players and non-soccer players. Dribble feet (F =45.859 and P <0.001) was the discriminating motor coordination test.

Table tennis

A stepwise discriminant analysis showed that there were no measures of anthropometry and physical fitness that discriminated table tennis players from the rest of the test sample. Backward balance (F =6.147 and P =0.003) and moving sideways (F =6.188 and P <0.014) were the discriminating motor coordination tests.

Triathlon

Triathletes had a lower body fat%. (F =6.747 and P =0.010). For physical fitness better scores for endurance shuttle run (F =21.953 and P <0.001) and lower scores for sprint 30m (F =23.077 and P <0.001) discriminated between triathletes and non-triathletes and there were no discriminating motor coordination tests.

Volleyball

It was shown that volleyball players had longer lower limbs (F =25.255 and P <0.001). For physical fitness, better scores for standing broad jump (F =30.215 and P <0.001), counter movement jump (F =53.921 and P <0.001), sprint 30m (F =36.083 and P <0.001) and shuttle run (F =25.630 and P <0.001) and lower scores for knee push-ups (F =41.913 and P <0.001) discriminated between volleyball and non-volleyball players. Better scores for throwing distance (F =16.687 and P <0.001) and lower scores for dribble feet (F =14.777 and P <0.001) and backward balance (F =1.890 and P <0.001) were the discriminating motor coordination tests.

Using relevant talent characteristics to identify athletes from nine different sports

Discriminant functions for the sequential discriminant analysis can be found in Table 13.

Badminton

These results revealed that knee push-ups (F =6.082 and P =0.015), sprint 5m (F =5.581 and P =0.020), counter movement jump (F =3.115 and P =0.080) and throwing distance (F =31.536 and P <0.001) accounted for a 93.6% correct identification of badminton players (rcan =0.490 and Wilks' Λ =0.760 and P <0.001). The discriminant functions classified 4 out of 12 badminton players correctly and 1 out of 129 non-badminton players were classified as a false positive.

Basketball

It was revealed that height (F =23.387 and P <0.001), sitting height (F =6.221 and P =0.014), sit-ups (F =4.780 and P =0.030) and dribble hands (F =21.368 and P <0.001) accounted for an 85.1% correct identification of basketball players (rcan =0.486 and Wilks' Λ =0.764 and P <0.001). The discriminant functions classified 11 out of 27 basketball players as false negatives and 10 non-basketball players out of 114 were classified as false positives.

Gymnastics

Height (F =15.881 and P <0.001), sit and reach (F =23.026 and P <0.001), shoulder rotation (F =26.310 and P <0.001), knee push-ups (F =15.036 and P <0.001) and dribble run accounted for a 97,2% correct identification of gymnasts (rcan =0.517 and Wilks' Λ =0.733 and P <0.001). The discriminant functions classified 4 out of 8 gymnasts correctly and all 133 non-gymnasts were classified as false positives.

Handball

Only dribble hands (F =6.717 and P =0.011) accounted for an 80.1% correct identification of handball players (rcan =0.215 and Wilks' Λ =0.954 and p <0.011). The discriminant functions classified none of the handball players correctly while all non-handball players were classified false negatives.

Table 13: Coefficients for Fisher's linear discriminant functions for sport membership based on significant characteristics.

	Badminton		Basketball		Gymnastics		Handball		Judo		Soccer		Table tennis		Triathlon		Volleyball	
% correctly classified	93.6		85.1		97.2		80.1		95.7		92.2		95.0		91.4		95.0	
Sport membership	athletes	others	athletes	others	athletes	others	athletes	others	athletes	others	athletes	others	athletes	others	athletes	others	athletes	others
Anthropometry																		
Height (cm)	-	-	1.383	1.080	2.592	2.688	-	-	169.179	168.612	2.202	2.248	-	-	-	-	-	-
Sitting height (cm)	-	-	2.366	2.846	-	-	-	-	-	-	-	-	-	-	-	-	5.033	5.039
Weight (kg)	-	-	-	-	-	-	-	-	226.396	225.434	-	-	-	-	-	-	-	-
Body fat (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.261	1.489	-	-
BMI	-	-	-	-	-	-	-	-	745.657	742.108	-	-	-	-	-	-	-	-
Physical characteristics																		
Sit and reach (cm)	-	-	-	-	-0.200	-0.158	-	-	-	-	-	-	-	-	-	-	-	-
Shoulder rotation (cm)	-	-	-	-	0.110	-0.056	-	-	-	-	-	-	-	-	-	-	-	-
Sprint 5m (s)	203.011	214.916	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sprint 30m (s)	-	-	-	-	-	-	-	-	-	-	128.041	130.682	-	-	-	-	270.553	258.676
Shuttle run (s)	-	-	-	-	-	-	-	-	35.106	35.978	-	-	-	-	-	-	19.631	20.277
Sit-ups (n)	-	-	0.510	0.435	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knee push-ups (n)	1.031	0.921	-	-	2.998	2.879	-	-	-	-	-	-	-	-	-	-	-	-
Counter movement jump (cm)	1.330	1,434	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.828	5.374
Standing broad jump (cm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.155	1.114
Endurance shuttle run (min)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.022	6.024	-	-
Motor characteristics																		
Backward balance (n)	-	-	-	-	-	-	-	-	-	-	-	-	0.221	0.329	-	-	-	-
Jumping sideways (n)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moving sideways (n)	-	-	-	-	-	-	-	-	-	-	-	-	0.687	0.534	-	-	-	-
Dribble run (s)	-	-	-	-	20.792	21.409	-	-	-	-	-	-	-	-	-	-	-	-
Dribble hands (s)	-	-	5.003	5.374	-	-	2.447	2.680	-	-	-	-	-	-	-	-	-	-
Dribble feet (s)	-	-	-	-	-	-	-	-	-	-	1.015	1.414	-	-	-	-	-	-
Throwing distance (m)	2.276	1.710	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.611	3.471
Constant	-200.138	-192.158	-287.695	-279.375	-400.991	-414.590	-453.350	-20.566	-15679.670	-15579.974	-483.178	-511.895	-31.118	-23.561	-54.050	-44.005	-1372.606	-1372.606

Note: athletes = membership; others = non-membership

Fisher's linear discriminant functions for badminton (example)

$D_{badminton}$ *= 1.031 * Knee push-ups + 203.011 * Sprint 5m + 1.330 * counter movement jump + 2.276 * throwing distance – 200.138*

D_{others} *= 0.921 * Knee push-ups + 214.916 * Sprint 5m + 1.434 * counter movement jump + 1.710 * throwing distance – 192.158*

Judo

Height (F =11.343 and P <0.001), body weight (F =2.129 and P =0.147), body mass index (F =2.586 and P =0.110) and shuttle run (F =6.636 and P =0.011) accounted for a 95.7% correct identification of judo athletes (rcan =0.397 and Wilks’ Λ =0.843 and P <0.001). The discriminant functions classified 6 out of 8 judo athletes as false negatives and all non-judo athletes were classified correctly.

Soccer

Height (F =4.261 and P =0.041), sprint 30m (F =2.470 and P =0.118) and dribble feet (F =45.859 and P <0.001) accounted for a 92.2% correct identification of soccer players (rcan =0.525 and Wilks’ Λ =0.725 and P <0.001). The discriminant functions classified 7 out of 20 soccer players as false negatives and 4 non-soccer players out of 121 were classified as false positives.

Table tennis

Backward balance (F =2.785 and P =0.097) and moving sideways (F =6.188 and P <0.014) accounted for a 95.0% correct identification of table tennis players (rcan =0.209 and Wilks’ Λ =0.957 and p <0.047). The discriminant functions classified all 6 table tennis players as false negatives and 1 non-table tennis player out of 113 was classified as a false positive.

Triathlon

Body fat% (F =6.664 and P <0.011) and endurance shuttle run (F =21.953 and P <0.001) accounted for a 91.4% correct identification of triathletes (rcan =0.412 and Wilks’ Λ =0.831 and P <0.001). The discriminant functions classified 10 out of 12 triathletes, as false negatives and 2 non-triathletes out of 128 were classified as false positives.

Volleyball

Finally, sequential discriminant analysis revealed that sitting height (F =25.255 and P <0.001), standing broad jump (F =31.310 and P <0.001), counter movement jump (F52.965 and P <0.001), sprint 30m (F =0.589 and P =0.444), shuttle run (F =7.492 and P = .007) and throwing distance (F =16.687 and P <0.001) accounted for a 95.0% correct identification of volleyball players (rcan =0.680 and Wilks’ Λ =0.537 and p <0.001). The discriminant functions classified 5 out of 20 volleyball players as false negatives and 2 non-volleyball players out of 121 were classified as false positives.

Discussion

The results in this study show that a generic test battery like the FSC can be used to discriminate between athletes from different sports. Furthermore, this study has shown that from this generic test battery, relevant talent characteristics can be identified for each sport. Consequently, this research demonstrated that these characteristics could be used to discriminate between athletes who do and those who do not participate in a given sport. The FSC uses a set of 22 non-sport-specific anthropometrical, physical and motor characteristics to discriminate between participants from different sports. In the past, talent identification research has used different tests in different sports to evaluate similar characteristics, which makes the between-sports comparison difficult. Therefore, it is in the interest of talent identification programs to include the same test items in generic batteries such as the FSC.

The first step is to demonstrate that the used generic talent characteristics have enough power to discriminate between athletes from different sports. The FSC divided the sample in this study with a 96.4% correct classification rate into nine different sports, which indicates a high degree of consistency in the classification scheme. These findings indicate that the FSC discriminates athletes from various sports using a set of generic anthropometrical, physical fitness and motor coordination measurements. Batteries specifically designed for talent identification in youth gymnastics (Vandorpe, Vandendriessche et al., 2011) and soccer (Vandendriessche, Vaeyens et al., 2012) have the ability to identify the best performers, however because of their sport-specific nature, they lack the ability to be used in more general settings than their respective sports. Hence, these batteries are not the ideal tools to discriminate between sports, as the possibility of between-sports comparisons is a necessary prerequisite of any talent orientation tool.

The results from subsequent stepwise and sequential discriminant analyses used to identify relevant characteristics within sports in this study are in accordance with previous findings from scientific studies on performance profiles for these respective sports. (Allen 1991, Van Schuylenbergh, Eynde et al., 2004, Krstulovic, Sekulic et al., 2005, Gabbett and Georgieff 2007, Ooi, Tan et al. 2009, Ziv and Lidor 2009, Vandorpe, Vandendriessche et al., 2011, Vandendriessche, Vaeyens et al., 2012, Matthys, Vaeyens et al., 2013). The FSC revealed that body height is a relevant talent characteristic for basketball, volleyball, soccer, judo and gymnastics. Female gymnasts at an expert level have been shown to have a smaller stature (Vandorpe, Vandendriessche et al., 2011) while expert basketball (Ziv and Lidor 2009) and volleyball (Lidor, Hershko et al., 2007) players have longer lower limbs than their non-expert peers. Furthermore, the analyses in this study revealed that the relevant performance characteristics in the nine sports reported in this study, briefly are the following: flexibility in gymnastics, explosive leg strength in badminton and volleyball, speed and agility in badminton, judo, soccer and volleyball, upper body strength in badminton, basketball and gymnastics, cardio-respiratory endurance in triathletes, dribbling skills in handball, basketball and soccer and overhead throwing skills in badminton and gross motor coordination in table tennis players.

The strengths of this study are first of all its unique approach. This study used a generic testing battery in sample of 141 U18 athletes from nine different sports to identify relevant performance characteristics for each sport. The athletes used in this study trained and performed at the highest level for their respective ages and were in a stage of athletic development where performance was relatively consistent (Bompa and Haff 2009). Furthermore the multidimensional nature of the FSC allows for a more complete assessment of each athlete while not overlooking the specific nature of each sport involved. However this study also showed some limitations. It assessed only boys and had a relatively small sample size especially in table tennis (n= 6), triathlon (n=6) and gymnastics (n=8), although, this was a group of youth elites that passed several levels of selection by their respective federations before starting at the “Flemish elite sport schools”. The sample consists of the next generation of senior athletes active at international level. Future research is needed to elucidate to what extent the profiles identified will be valid to orient children and adolescents towards the sport that best matches their anthropometrical, physical and coordination profiles and to apply these findings to talent identification at younger age groups.

When sports policy balances between 'Sport-for-all" and "Elite" programs, talent detection might be a step towards a long-term sports practice. An active start in sports with all positive effects of an all-around development pathway is important for the development of young children (Fransen, Pion et al., 2012). Supporting talent detection programs, directing children towards sports that optimally suit their specific, individual characteristics might increase their chances to survive on the long way to the top. However, the place to reach all children is at school, primary schools currently play a minimal role in the detection of talented athletes (Elferink-Gemser 2013). A screening by means of a generic test battery in schools provides perspectives for talent detection and should precede talent identification in sports clubs. Most of the existing test batteries used for talent identification are a blend of generic and sport specific field tests. Talent detection with a more generic screening should precede talent identification. Such a generic test battery with the potential for orientation towards a sport that fits the characteristics of a child has the advantage that the examiner does not need to be highly trained in coaching for one or more specific sports. The use of generic tests allows that the ‘expert’s eye’ is not necessarily involved at this stage, opening the window for large-scale implementation of an instrument like the FSC. Similarly, there is no need for sophisticated test material at this stage. For coaches involved in talent development programs, the use of a generic test battery might be useful for the evaluation of young athletes on a regular basis. Using non-sport specific tests –or at least limiting the use of them- has the advantage that the bias due to differences in training history of sport specific skills, which are often part of the more frequently used test batteries, is limited.

In conclusion, the results in this study show that the FSC confirms that elite adolescent boys show differences in generic talent characteristic that distinguish them according to their particular sport. The FSC can also identify relevant talent characteristics for each sport, which could be used in the purposeful orientation of talented individuals according to their strengths and weaknesses.

References

1. Abbott, A. and D. Collins (2002). "A theoretical and empirical analysis of a 'state of the art' talent identification model." High Ability Studies 13(2): 157-178.
2. Allen, G. D. (1991). "Physiological-Characteristics of Elite Australian Table-Tennis Athletes and Their Responses to High-Level Competition." Journal of Human Movement Studies 20(3): 133-147.
3. Bompa, T. and G. G. Haff (2009). Periodization: Theory and methodology of training Champaign, IL, Human Kinetics.
4. Bruininks, R. H. and B. D. Bruininks (2006). BOT-2: Bruininks-Oseretsky Tests of Motor Proficiency. Minneapolis, AGS Publishing.
5. Bullock, N., J. P. Gulbin, D. T. Martin, A. Ross, T. Holland and F. Marino (2009). "Talent identification and deliberate programming in skeleton: Ice novice to Winter Olympian in 14 months." Journal of Sports Sciences 27(4): 397-404.
6. Council of Europe. Committee for the Development of Sport. EUROFIT: Handbook for the EUROFIT tests of physical fitness. Rome: Secretariat of the Committee for the Development of Sport within the Council of Europe; 1988
7. De Bosscher, V., J. Bingham, S. Shibli, M. Van Bottenburg and P. De Knop (2008). The Global Sporting Arms Race: an International Comparative Study on Sports Policy Factors Leading to International Sporting Success. Oxford, Meyer & Meyer.
8. Elferink-Gemser, M. (2013). Olympia exists: Pushing boundaries for talented athletes. Arnhem, The Netherlands, HAN University of Applied Sciences Press.
9. Fransen, J., J. Pion, J. Vandendriessche, B. Vandorpe, R. Vaeyens, M. Lenoir and R. M. Philippaerts (2012). "Differences in physical fitness and gross motor coordination in boys aged 6-12 years specializing in one versus sampling more than one sport." Journal of Sports Sciences 30(4): 379-386.
10. Gabbett, T. and B. Georgieff (2007). "Physiological and anthropometric characteristics of australian junior national, state,and novice volleyball players." Journal of Strength and Conditioning Research 21(3): 902-908.
11. Hoare, D. G. and C. R. Warr (2000). "Talent identification and women's soccer: An Australian experience." Journal of Sports Sciences 18(9): 751-758.
12. Kiphard, E. J. and F. Schilling (2007). Körperkoordinationstest für Kinder. Weinheim: Beltz, Test GmbH.
13. 13. Krstulovic, S., D. Sekulic and H. Sertic (2005). "Anthropological determinants of success in young judoists." Collegium Antropologicum 29(2): 697-703.
14. Leone, M. and G. Lariviere (1998). "Anthropometric and biomotor characteristics of elite adolescent male athletes competing in four different sports." Science & Sports 13(1): 26-33.
15. Leone, M., G. Lariviere and A. S. Comtois (2002). "Discriminant analysis of anthropometric and biomotor variables among elite adolescent female athletes in four sports." Journal of Sports Sciences 20(6): 443-449.
16. Lidor, R., Y. Hershko, A. Bilkevitz, M. Arnon and B. Falk (2007). "Measurement of talent in volleyball: 15-month follow-up of elite adolescent players." Journal of Sports Medicine and Physical Fitness 47(2): 159-168.
17. Lohman, T. M., A. F. Roche and R. Martorell (1988). Anthropometric standardization reference manual. Champaign IL, Human Kinetics.
18. Malina, R. M., & Koziel, S. M. (2014). Validation of maturity offset in a longitudinal sample of Polish boys. Journal of Sports Sciences, 32(5), 424-437. doi: Doi 10.1080/02640414.2013.828850
19. Matthys, S. P., R. Vaeyens, J. Fransen, D. Deprez, J. Pion, J. Vandendriessche, B. Vandorpe, M. Lenoir and R. Philippaerts (2012). "A longitudinal study of multidimensional performance characteristics related to physical capacities in youth handball." J Sports Sci.
20. Matthys, S. P., R. Vaeyens, J. Fransen, D. Deprez, J. Pion, J. Vandendriessche, B. Vandorpe, M. Lenoir and R. Philippaerts (2013). "A longitudinal study of multidimensional performance characteristics related to physical capacities in youth handball." J Sports Sci 31(3): 325-334.
21. Matthys, S. P. J., R. Vaeyens, J. Vandendriessche, B. Vandorpe, J. Pion, A. J. Coutts, M. Lenoir and R. M. Philippaerts (2011). "A multidisciplinary identification model for youth handball." European Journal of Sport Science 11(5): 355-363.
22. Mirwald, R. L., A. D. G. Baxter-Jones, D. A. Bailey and G. P. Beunen (2002). "An assessment of maturity from anthropometric measurements." Medicine and Science in Sports and Exercise 34(4): 689-694.
23. Mohamed, H., R. Vaeyens, S. Matthys, M. Multael, J. Lefevre, M. Lenoir and R. Philippaerts (2009). "Anthropometric and performance measures for the development of a talent detection and identification model in youth handball." Journal of Sports Sciences 27(3): 257-266.

24. Mohamed, H. S. (2009). Contribution of maturation, anthropometric and physical performance measures in talent detection and identification in youth handball players: a cross-sectional study. Doctor in Physical Education Doctoral dissertation, Ghent University.
25. Ooi, C. H., A. Tan, A. Ahmad, K. W. Kwong, R. Sompong, K. A. Ghazali, S. L. Liew, W. J. Chai and M. W. Thompson (2009). "Physiological characteristics of elite and sub-elite badminton players." J Sports Sci 27(14): 1591-1599.
26. Régnier, G., J. H. Salmela and J. C. Russell (1993). Talent detection and development in sport. Handbook of research in sport psychology. R. N. Singer, M. Murphy and L. K. Tennant. New York, Wiley: 290-313.
27. Vaeyens, R., M. Lenoir, A. M. Williams and R. M. Philippaerts (2008). "Talent identification and development programmes in sport - Current models and future directions." Sports Medicine 38(9): 703-714.
28. Van Rossum, J. H. and F. Gagné (2005). Talent development in sports. Wako, Prufrock Press.
29. Van Schuylenbergh, R., B. V. Eynde and P. Hespel (2004). "Prediction of sprint triathlon performance from laboratory tests." Eur J Appl Physiol 91(1): 94-99.
30. Vandendriessche, J. B., R. Vaeyens, B. Vandorpe, M. Lenoir, J. Lefevre and R. M. Philippaerts (2012). "Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years)." Journal of Sports Sciences 30(15): 1695-1703.
31. Vandorpe, B., J. Vandendriessche, R. Vaeyens, J. Pion, J. Lefevre, R. Philippaerts and M. Lenoir (2011). "Factors Discriminating Gymnasts by Competitive Level." International Journal of Sports Medicine 32(8): 591-597.
32. Vandorpe, B., J. Vandendriessche, R. Vaeyens, J. Pion, S. Matthys, J. Lefevre, R. Philippaerts and M. Lenoir (2012). "Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach." Journal of Science and Medicine in Sport 15(3): 220-225.
33. Williams, A. M. and T. Reilly (2000). "Talent identification and development in soccer." Journal of Sports Sciences 18(9): 657-667.
34. Ziv, G. and R. Lidor (2009). "Physical Attributes, Physiological Characteristics, On-Court Performances and Nutritional Strategies of Female and Male Basketball Players." Sports Medicine 39(7): 547-568.

Champions aren’t made in the gym.

Champions are made from something they have deep inside them

a desire, a dream, a vision.

(Muhammad Ali)

2.2.2 PAPER 3: THE VALUE OF NON-SPORT-SPECIFIC CHARACTERISTICS FOR TALENT ORIENTATION IN YOUNG MALE JUDO, KARATE AND TAEKWONDO ATHLETES

SELF-CONFIDENCE NON-VIOLENCE
Archives of Budo
Science of Martial Arts
and Extreme Sports
ISSN 2300-8822

Johan Pion, Job Fransen, Matthieu Lenoir and Veerle Segers

2014

Archives of Budo (10), p. 147-152

Abstract

Background and Study Aim: The present study aims to discriminate young male taekwondo, judo, and karate athletes from two age groups. It is hypothesized that a generic test battery (i.e. consisting of non-sport specific items) can allocate athletes in their respective sports. It is also expected that due to training and experience, differences between sports would be larger in the oldest age group.

Material and Methods: Fifty-six highly trained taekwondo, judo, and karate athletes U13 (11.596 ± 0.578 years; n = 30) and U18 (16.097 ± 0.844 years; n = 26) completed five anthropometrical, six physical performance and three motor coordination tests. Discriminant analyses were used to investigate relevant performance measures while MANOVAs were conducted to elucidate the differences between taekwondo, judo and karate.

Results: The classification results for both discriminant analyses U13 and U18 showed a perfect classification (100%) of the athletes in their respective sports. U18 showed higher multivariate differences between the three martial arts i.e. for anthropometrical measures ($F_{2.148}$, P =0.044, ES =0.36), physical performance characteristics ($F_{2.216}$, P =0.033, ES =0.43) and motor coordination ($F_{6.697}$, P <0.001, ES =0.49) when compared to their younger counterparts. Judo athletes had the highest scores for sit and reach, handgrip, counter movement jump and balance beam. While taekwondo athletes had the highest scores for sit-ups, sprint 5m and 30m and jumping sideways.

Conclusions: Generic talent characteristics allow for a successful discrimination between judo, taekwondo and karate athletes, while the differences between the martial arts profiles are more pronounced in older athletes.

Key words: anthropometrical indicators • combat sports • motor coordination tests • Olympic sport • physical performance

Introduction

A variety of performance characteristics and anthropometric characteristics are required for athletes to succeed in a wide range of combat sports. It is however possible, that basic requirements for combat sports are similar. This might allow for a transfer of talent between sports when the desired multi-disciplinary talent characteristics are present. An excellent example is Belgian athlete Catherine Jacques, a multiple national champion and four-time bronze medallist for her category at the European Judo Championships. She was unable to win another medal during the 2004 Summer Olympic podium and instead transferred her talent to ju-jitsu to become the world champion in 2011. Next to the issue of talent transfer, understanding similarities between combat sports might provide talent orientation programs with valuable information when directing young children towards sports that optimally suit their individual profiles. Hence, in countries with a relatively small population where no talent can go to waste, understanding the underlying performance characteristics that relate to international success in karate, judo and taekwondo might help the talent identification as well as the talent transfer process between different combat sports.

In the following overview the key characteristics of karate, taekwondo and judo will be briefly described. First, karate is a martial art characterized by punches of both upper and lower limbs. As such, where competitors use hits with upper and lower limbs [1]. Height and leg length are important talent characteristics, while leg power, core stability and flexibility are basic requirements for kicking [2, 3]. Anthropometric studies revealed that elite karate athletes had a lower fat percentage and longer lower limbs than their peers from other sports [4, 5] Studies investigating performance characteristics elucidated that explosive strength, balance, flexibility and agility contribute to faster executed karate skills [4, 5]. Second, taekwondo is an Olympic sport, which requires explosive strength, flexibility and balance. Height and leg length are essential, while balance, leg power, core stability and flexibility have a beneficial effect on taekwondo performance [6, 7]. Competitors must be able to move with high velocity, speed and power. A surplus of body mass can hinder this ability especially if this excess mass is in the form of fat which is metabolically inactive when compared to muscle [7]. Explosive strength, balance, flexibility and agility contribute to faster and better-executed taekwondo skills [6-8]. Third, judo is an Olympic sport classified among the sports that require explosive power of an anaerobic character [9]. It is a high-intensity intermittent, grappling combat sport where athletes are classified by gender and body mass categories [10]. Explosive strength, balance, flexibility and agility contribute to faster judo actions [11, 12].

In sum, research using a generic testing battery to reveal performance related characteristics in combat sports showed that height and leg length are important talent characteristics in karate and taekwondo, because leg power, core stability and flexibility are basic requirements for kicking [2, 3, 6, 8]. Explosive strength, balance, flexibility and agility contribute to faster executed taekwondo, judo and karate skills [4-6, 11].

Next to the anthropometric and physical characteristics, each of the three combat sports is featured by specific technical skills, the mastery of which requires specific training and a well-developed motor coordination. Previous studies have shown that general motor coordination generally discriminates elite from sub-elite athletes [13]. Given the technical complexity and speed of execution required in martial arts, it is assumed that motor coordination also plays an important role in these sports.

Studies comparing performance characteristics in multiple combat sports are scarce [14, 15] and to our knowledge, no study has compared performance related characteristics in taekwondo, karate and judo specifically. Therefore, this study aims to discriminate young male U13 and U18 athletes from three different combat sports using a generic testing battery. It is hypothesized that young male U13 and U18 from three different combat sports, i.e. taekwondo, karate and judo can be discriminated using a generic test battery. It is also expected that in the oldest age group the differences for the measured talent characteristics would be more pronounced between the sport disciplines due to training and 'natural' selection.

Material and Methods

Participants and design: A sample of 56 highly trained athletes participated in this study and were divided into two age categories: U13: 11.596 ± 0.578 years (n = 30) and U18: 16.097 ± 0.844 years (n = 26). These athletes were participants in karate ($n_{U13} = 9$; $n_{U18} = 6$), taekwondo ($n_{U13} = 11$; $n_{U18} = 9$) and judo ($n_{U13} = 10$; $n_{U18} = 11$). This study has been conducted in accordance with recognized ethical standards in sport and exercise science research [16] and was approved by the local Ethics Committee of the Ghent University Hospital. For all participants written informed parental consent was obtained. None of the participants refused participation.

Measurements: The participants completed five anthropometrical, six physical performance and three motor coordination tests assessed by a team of experienced examiners of the Department of Movement and Sports Sciences, Ghent University (Belgium). At any given time, instruction and demonstration were standardized according to the test guidelines. The athletes performed all tests barefoot with exception of the sprints, the counter movement jump and the endurance shuttle run test, which all were performed with running shoes.

Anthropometry: Height (H) and Sitting Height (SH) (0.1 cm, Harpenden, portable Stadiometer, Holtain, UK), body weight (BW) and body fat percentage (BF) (0.1 kg, Tanita, BC-420SMA, Tokyo, Japan) was assessed according to previously described procedures [17] and manufacturer guidelines. Height and weight values were used to calculate Body Mass Index (BMI).

Physical Performance: **Flexibility** was assessed by the sit-and-reach test of the Eurofit test battery with an accuracy of 0.1 cm [18]. To assess **explosive leg power**, counter movement jump was performed. The participants performed three single jumps without arm swing recorded with an OptoJump device (MicroGate, Bolzano, Italy). The highest of three jumps was used for further analysis (0.1 cm). **Static strength** was measured by the handgrip [18]. **Speed** was assessed by two maximal sprints of 30 m with split time measured at 5 m. The recovery time between each sprint was set at 2 min. The fastest time for sprint 5 m and for sprint 30 m was used for analysis [19]. The sprint tests were recorded with MicroGate Racetime2 chronometry and Polifemo Light photocells at an accuracy of 0.001 s (MicroGate, Bolzano, Italy). **Upper body strength** was measured through the performance of sit-ups according to the BOT2 procedures [20], requiring the athletes to execute as many repetitions as possible in 30 s.

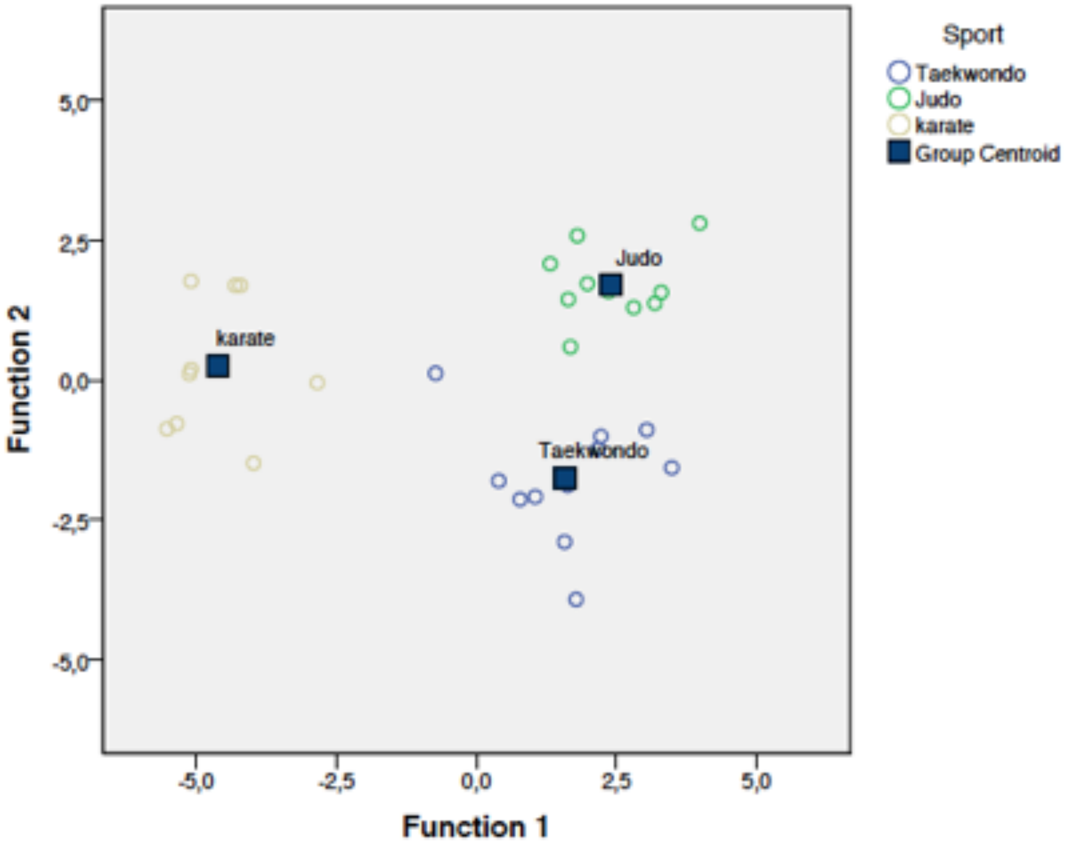
Motor Coordination: Gross motor coordination was evaluated by means of three subtests of the "Körperkoordinationstest für Kinder" (KTK) [21]. The fourth test hopping for height was not performed, due to risk on injuries at the ankles, cited by Prätorius & Milani [22]. The first subtest assessed the backward balance. Therefore, participants had to walk backwards along balance beams of decreasing width (6 cm; 4.5 cm and 3 cm respectively). Secondly, speed of lower limbs was measured with a two-legged jumping sideways test, performed over a wooden slat (2 x 15 s), summing the number of jumps over the two trials. The third test measured general body coordination. Participants had to move sideways on wooden platforms (2 x 20 s), summing the number of relocations over two trials.

Statistical analyses: All data were analysed using SPPS for Windows (v. 20.0). The present study had a cross sectional design involving two age groups: U13 and U18. First, two canonical discriminant analyses were used to investigate relevant physical performance measures in karate, judo and taekwondo for both age groups. In those analyses, belonging to either of three different sports was the grouping variable and the independent variables were the test results obtained from the five anthropometrical, six physical and three motor coordination characteristics. Second, Multivariate Analyses of Variance (MANOVA) was conducted to elucidate the differences between taekwondo, judo and karate in two age groups, with anthropometry, physical performance characteristics and motor coordination between karate, judo and taekwondo as fixed factor. In addition, the magnitude of the differences between the levels was estimated using Partial Eta Squared with cut-off scores of 0.01 (small), 0.06 (moderate) and 0.14 (large) [23]. The level of significance was set at $p < 0.05$.

Results

Discriminating between fighting sports

A first discriminant analysis revealed two significant discriminant functions FD1 and FD2 in the U13 sample of young trained male athletes. FD1 (r_{can} =0.954 and Wilks’ Λ =0.027 and $p < 0.001$) accounted for 81.4% of the variance between sports participants while FD2 (r_{can} = 0.837 and Wilks’ Λ = 0.299 and $P = 0.025$) reflected 18.6% of the variance. The results also showed that 100% of the athletes were correctly classified in their respective sports. 29 illustrates how well FD1 and FD2 discriminated between each sport in terms of its profile, using the group means of the predictor variables.



29: Differences for young trained male athletes U13, based on canonical discriminant functions calculated from the 14 generic tests (FSC).

Note 1. The scatterplot has the canonical discriminant function coefficients as its axes, with Function 1 on the X and function 2 on the Y-axes. The three groups cluster within the 2-dimensional space, indicating that the functions discriminate clearly between judo, karate and taekwondo. The first function on the X-axis was the most helpful in distinguishing between sports with the highest correlation between jumping sideways and DF1. The centroids, which are the mean discriminant score for each group, are indicated by a square.

Note 2. Functions at Group Centroids Karate Function 1 = -4.607; Function 2 = 0.251; Judo Function 1 = -2.405; Function 2 = 1.702; Taekwondo Function 1 = 1.583; Function 2 = -1,753

The second discriminant analysis also revealed also two significant functions FD1 and FD2 in the sample highly trained male athletes **U18**. FD1 (r_{can} =0.916 and Wilks' Λ =0.048 and

P = 0.006) accounted for 69.3% of the variance between sports participants while FD2 (r_{can} = 0.836 and Wilks' Λ = 0.301 and P = 0.101) reflected 30.7% of the variance. All athletes (100%) were correctly classified in their respective sports. Figure 30 illustrates the differences between each sport for highly trained male athletes U18 based on canonical discriminant functions calculated from the predictor variables.

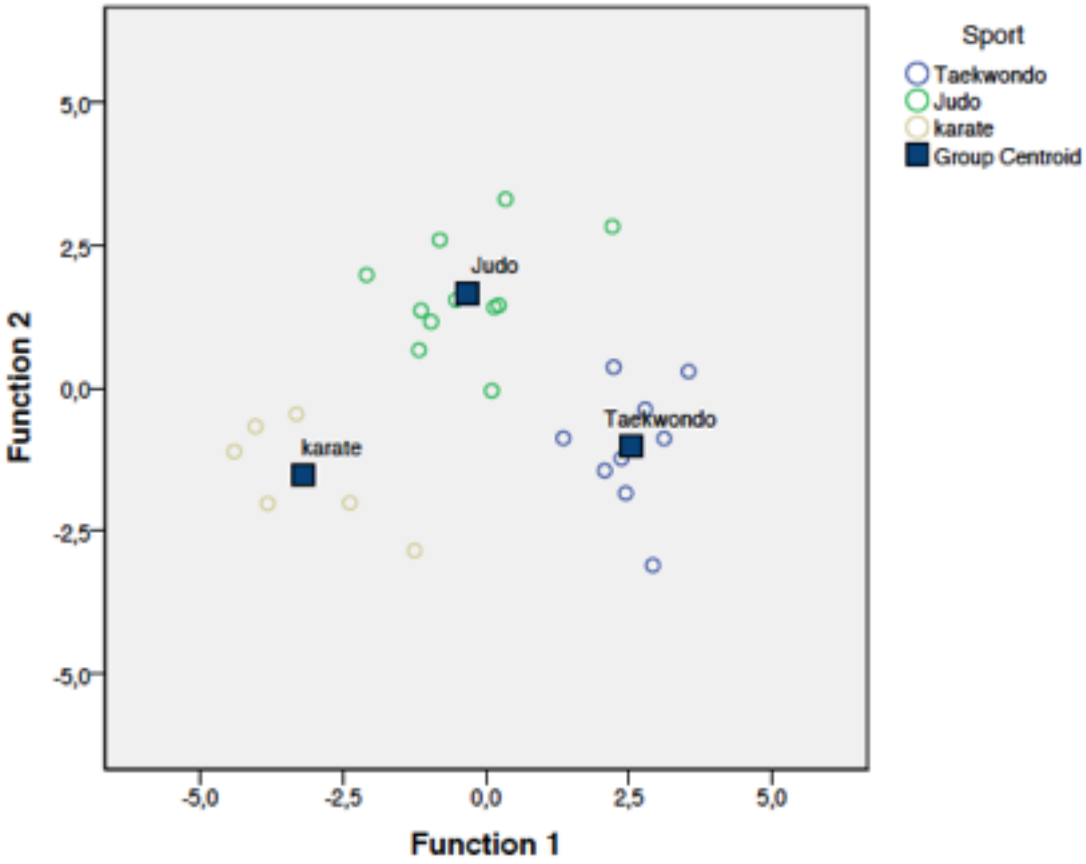


Figure 30: Differences for highly trained male athletes U18, based on canonical discriminant functions calculated from the 14 generic tests (FSC).

Note 3. The scatterplot has the canonical discriminant function coefficients as its axes, with Function 1 on the X and function 2 on the Y-axes. The three groups cluster within the 2-dimensional space, indicating that the functions discriminate clearly between judo, karate and taekwondo. The first function on the X-axis was the most helpful in distinguishing between sports with the highest correlation between jumping sideways and DF1. The centroids, which are the mean discriminant score for each group, are indicated by a square.

Note 4. Functions at Group Centroids Karate Function 1 = -3.197; Function 2 = -1.520; Judo Function 1 = -0.332; Function 2 = 1.657; Taekwondo Function 1 = 2.537; Function 2 = -1,012

Identifying relevant talent characteristic for each sport

In the sample young trained male athletes **U13** (11.596 ± 0.578 y) no significant differences in anthropometrical measures ($F_{1.111}$ and P = 0.375, ES = 0.19) occurred. The analysis of physical performance data revealed significant multivariate effects between the three martial arts ($F_{3.208}$ and P = 0.002, ES = 0.47). Post hoc analysis showed that none of the characteristics was significantly different between the three sports. For motor coordination highly significant differences between the martial arts were found ($F_{9.165}$ and P < 0.001, ES = 0.52), Post hoc analysis demonstrated significant differences for jumping sideways ($F_{9.165}$ and P < 0.001, ES = 0.52).

Table 14: Mean (SD) from MANOVAs for young trained male athletes U13 in karate, judo and taekwondo with corresponding F-values, p-values and effect sizes for anthropometry, physical performance, and motor coordination.

	Karate	Judo	Taekwondo	F-value	p-value	Effect Size
	n=9	n=10	n=11			
Age (years)	11.8 (0.7)	11.7 (0.6)	11.3 (0.4)			
MANOVA anthropometry				**1.111**	**0.375**	**0.19**
Body Height (cm)	151.5 (9.3)	148.6 (7.1)	144.3 (8.0)			
Sitting **heigth** (cm)	78.1 (4.3)	77.4 (4.1)	75.8 (3.2)			
Body Weight (kg)	37.3 (7.5)	38.4 (5.3)	36.9 (6.9)			
Body Fat (%)	11.7 (2.3)	12.7 (3.4)	15.1 5.4)			
BMI (kg/m2)	16.1 (1.4)	17.3 (1.9)	17.6 2.2)			
MANOVA physical performance				**3.208**	**0.002**	**0.47**
Sit and Reach (cm)	15.0 (6.5)	18.0 (4.5)	23.5 (3.0)	N.S.		
Hand Grip (kg)	21 (5)	19 (4)	20 (6)	N.S.		
Sit-ups (n/30s)	35 (4)	40 (3)	34 (8)	N.S.		
Counter Movement Jump (cm)	24.2 (4.0)	23.8 (3.8)	22.1 (3.6)	N.S.		
Sprint 5m (s)	1.29 (0.07)	1.32 (0.11)	1.25 (0.06)	N.S.		
Sprint 30m (s)	5.70 (0.41)	5.54 (0.30)	5.38 (0.22)	N.S.		
MANOVA motor coordination				**9.165**	**<0.001**	**0.52**
Balancing Backwards (points)	50 (11)	48 (10)	53 (9)	N.S.		
Jumping Sideways (points)	71 (7)	95 (10)	90 (11)	15.544	<0.001	0.535
Moving Sideways (points)	54 (6)	55 (6)	52 (5)	N.S.		

In the highly qualified male athletes **U18** (16.097 ± 0.844 y), a significant main effect of the combat sport discipline for anthropometrical measures ($F_{2.148}$ and P = 0.044, ES = 0.36) was found. However, none of the measures showed significant differences between the three sports in Post Hoc analysis.

The MANOVA on physical performance characteristics resulted in a significant difference between karate, judo and taekwondo ($F_{2.216}$ and P = 0.033, ES = 0.43). Post hoc analyses indicated differences in flexibility ($F_{8.530}$ and P = 0.002, ES = 0.43), static strength ($F_{6.069}$ and P = 0.008, ES = 0.35), upper body strength ($F_{4.521}$ and P =

0.022, ES = 0.28), and speed ($F_{4.445}$ and P = 0.023, ES = 0.28). Finally, highly significant differences for motor coordination were observed between the martial arts ($F_{6.697}$ and P < 0.001, ES = 0.49). Post hoc analysis demonstrated significant differences for balancing backwards ($F_{5.014}$ and P = 0.016, ES = 0.30); jumping sideways ($F_{20.000}$ and P < 0.001, ES = 0.64) and moving sideways ($F_{3.951}$ and P = 0.033, ES = 0.26).

Table 15: Mean (SD) from MANOVAs for highly qualified male athletes U18 in karate, judo and taekwondo with corresponding F-values, p-values and effect sizes for anthropometry, physical performance, and motor coordination.

	Karate	Judo	Taekwondo	F-value	p-value	Effect Size
	n=6	n=11	n=9			
Age (years)	16.0 (1.1)	16.2 (0.8)	16.0 (0.7)			
MANOVA anthropometry				**2.148**	**0.044**	**0.36**
Body Height (cm)	169.9 (10.0)	167.1 8.2)	171.8 (3.8)	N.S.		
Sitting heigth (cm)	86.7 (5.6)	88.9 (4.9)	90.7 (2.7)	N.S.		
Body Weight (kg)	57.3 (17.8)	61.4 (7.2)	60.5 (7.2)	N.S.		
Body Fat (%)	10.9 (7.4)	12.9 (2.4)	10.9 (2.1)	N.S.		
BMI (kg/m2)	19.5 (4.3)	21.9 (1.1)	20.5 (2.2)	N.S.		
MANOVA physical performance				**2.216**	**0.033**	**0.43**
Sit and Reach (cm)	17.0 (10.5)	32.0 (7.5)	23.5 (3.0)	8.530	0.002	0.43
Hand Grip (kg)	33 (9)	47 (7)	42 (7)	6.069	0.008	0.35
Sit-ups (n/30s)	38 (7)	44 (4)	49 (8)	4.521	0.022	0.28
Counter Movement Jump (cm)	30.0 (9.3)	33.3 (4)	32.1 (3.7)	N.S.		
Sprint 5m (s)	1.20 (0.09)	1.14 (0.06)	1.11 (0.07)	N.S.		
Sprint 30m (s)	5.05 (054)	4.59 (0.27)	4.54(0.29)	4.445	0.023	0.28
MANOVA motor coordination				**6.697**	**<0.001**	**0.49**
Balancing Backwards (points)	48 (18)	66 (7)	57 (13)	5.014	0.016	0.30
Jumping Sideways (points)	80 (12)	99 (8)	114 (12)	20.000	<0.001	0.64
Moving Sideways (points)	56 (7)	68 (10)	68 (9)	3.951	0.033	0.26

Discussion

The present cross-sectional study investigated to what extent boys U13 and U18 from three different combat sports could be discriminated by a generic test battery and if the differences would be more pronounced in the oldest age group. The main finding was that generic talent characteristics allow for a successful discrimination between judo, taekwondo and karate athletes. In both age groups, 100% of the athletes were correctly classified in their respective sports. Leone and Colleagues [12] reported 86% correct classification for multi-disciplinary talent characteristics in four divergent types of sports i.e. tennis, figure skating, cycling and gymnastics. Discriminating karate, judo and taekwondo might be more problematic due to the similarities between the three martial arts, but the perfect classification rate in our study for both age groups aligned with our hypothesis. According to the second hypothesis, the differences between the martial arts become more pronounced with age. Furthermore, it was found that already before adolescence junior athletes present the necessary anthropometrical, physical and motor coordination characteristics to excel in their sport.

In this study no effect of sports participation on anthropometrical characteristics was found in this U13 sample. In the highly trained U18, multivariate differences between karate, judo and taekwondo were found, although post hoc analysis did not reveal anthropometrical differences. The registered differences between the three martial arts in the two age groups are not in line with previous research reporting a leaner body mass and longer legs for karate competitors [4, 5] a larger body length being advantageous for taekwondo athletes [6, 8, 24] and a higher lean body mass in elite judo athletes [25, 26].

In the U13 sample, an overall multivariate effect of sport discipline on physical performance scores was found, although none of the post hoc analyses revealed significant differences. Highly trained adolescents of the U18 group showed multivariate differences between the three martial arts and post hoc analyses demonstrated significant differences for flexibility; static strength; upper body strength speed and coordination with the highest values for sit and reach, handgrip, counter movement jump and balance beam occurring in the judo athletes. The ability to develop a strong grip and to maintain it during a judo match was reported by Franchini et al. [10] and reconfirmed in this study. Agility and explosive strength were linked to judo, support throwing, sweeping and clamping [11, 12]. Leg power, core stability and flexibility have been documented as prerequisites for kicking, in both taekwondo and karate [3, 5, 27]. In the present study taekwondo athletes had the highest scores for sit-ups, sprint 5 m and 30 m and jumping sideways.

General motor coordination has been proven a valuable indicator of an athlete’s potential for progression and as such an important talent characteristic in skill-based sports such as artistic gymnastics [13] and combat sports [28]. More-over Krstulovic et al. report that motor coordination and balance is better developed in elite judo and taekwondo athletes compared to non-elite [11]. Our study reinforced these finding showing significant differences in the sample of highly trained athletes for motor coordination between karate, judo and taekwondo.

The athletes that compete in one of both Olympic disciplines (judo and taekwondo) outperformed the Belgian national squad karate for all three motor coordination tests [21]. In the younger age group with trained boys U13, motor coordination differs already in favour of taekwondo and judo especially for jumping sideways. Those findings are an important indication that it might be important factor in determining who makes it into an expert level in these fighting sports and who does not.

When promoting martial arts, it is important to know that children might choose a sport with different objectives in mind. They can be attracted to different objectives at different points of their engagement with sport [29]. Their engagement to participate can either be recreational or competitive and at the same time one might be a competitive judo athlete and a recreational taekwondo athlete while learning karate. Youth athletes and their trainers, attempting to make it to the top need to be aware of the increasing demands of their sport. Therefore talent identification test batteries are important tools to evaluate if the athlete possesses the necessary talent characteristics and if he or she is still on track. Gulbin et al. found that contrary to a popular pyramidal concept of athlete development a single linear assault on expertise is rare, and that the common normative junior to senior competition transition is mostly characterized by complex oscillations featuring highly varied transitions [29].

The present study focuses on two age groups in which the importance of sport specific characteristics becomes more specific and shifts from motor coordination to more trainable characteristics i.e. speed and flexibility. The special demands that are typical for the training of children and adolescents lead to the question, whether age group training necessitates certain accents in regard to athletic performance in fighting sports. Régnier’s sliding population approach [30] take into consideration the different stages of performance and our findings are in accordance with the proposition that anthropometric and physical characteristics become more important as athletes reach a higher level. The strengths of this study include the use of anthropometrical and physical performance characteristics combined with motor coordination tests in different martial arts for different age groups. The limitation of a relatively small sample size is inherent to research in trained athletes, who are not numerous by definition. Nevertheless, generic talent characteristics included in the present study allow for a successful discrimination between judo, taekwondo and karate athletes. If not ignoring the trainers opinion and in addition to an individual screening of performance characteristics, this test battery provides opportunities for talent orientation.

Conclusion

Generic talent characteristics allow for a successful discrimination between judo, taekwondo and karate athletes, while the differences between the martial arts profiles are more pronounced in older athletes.

References

1. Sterkowicz-Przybycien KL. Body Composition and Somatotype of the Top of Polish Male Karate Contestants. Biol Sport 2010; 27(3): 195-201
2. Ravier GF, Grappe F, Rouillon JD. Application of force-velocity cycle ergometer test and vertical jump tests in the functional assessment of karate competitor. J Sports Med Phys Fitness 2004; 44(4): 349-355
3. Cesari P, Bertucco M. Coupling between punch efficacy and body stability for elite karate. J Sci Med Sport 2008; 11(3): 353-356
4. Giampietro M, Pujia A, Bertini I. Anthropometric features and body composition of young athletes practicing karate at a high and medium competitive level. Acta Diabetol 2003; 40 Suppl 1: S145-148
5. Imamura H, Yoshimura Y, Uchida K et al. Maximal oxygen uptake, body composition and strength of highly competitive and novice karate practitioners. Appl Human Sci 1998; 17(5): 215-218
6. Marković G, Misigoj-Duraković M, Trninić S. Fitness profile of elite Croatian female taekwondo athletes. Coll Antropol 2005; 29(1): 93-99
7. Kazemi M, Perri G, Soave D. A profile of 2008 Olympic Taekwondo competitors. J Can Chiropr Assoc 2010; 54(4): 243-249
8. Kazemi M, Waalen J, Morgan C et al., A profile of Olympic Taekwondo competitors. J Sports Sci Med 2006; 5: 114-121
9. Cem K, İlknur K, Serpil A et al. The Body composition and some conditional features of women judoists of the Turkish national team. Facta Universitatis. Phys Edu Sport 2010; 8(2): 133-139
10. Franchini E, Del Vecchio FB, Matsushigue KA et al. Physiological Profiles of Elite Judo Athletes. Sports Med 2011; 41(2):147-166
11. Krstulović S, Zuvela F, Katić R. Biomotor systems in elite junior judoists. Coll Antropol 2006; 30(4): 845-851
12. Franchini E, Takito MY, Kiss MAPDM et al. Physical fitness and anthropometrical differences between elite and non-elite judo players. Biol Sport 2005; 22(4): 315-328
13. Vandorpe B, Vandendriessche JB, Vaeyens R et al. The value of a non-sport-specific motor test battery in predicting performance in young female gymnasts. J Sports Sci 2012; 30(5): 497-505
14. Carter J. Size and Somatotype of Olympic Female Athletes at Montreal. Med Sci Sports Exerc 1981. 13(2): 121-144
15. Leone M, Lariviere G, Comtois AS. Discriminant analysis of anthropometric and biomotor variables among elite adolescent female athletes in four sports. J Sports Sci 2002; 20(6): 443-449
16. Harriss DJ, Atkinson G. International Journal of Sports Medicine - Ethical Standards in Sport and Exercise Science Research. Int J Sports Med 2009; 30(10): 701-702
17. Lohman TG, Roche AF, Martorell R. Anthropometric Standardization Reference Manual. Champaign III; Human Kinetics Books; 1988
18. Council of Europe. Committee for the Development of Sport. EUROFIT: Handbook for the EUROFIT tests of physical fitness. Rome: Secretariat of the Committee for the Development of Sport within the Council of Europe; 1988
19. Matthys SPJ, Vaeyenes R, Vandendriessche J et al. A multidisciplinary identification model for youth handball. Eur J Sport Sci 2011; 11(5): 355-363
20. Bruininks RH, Bruininks BD. Test of Motor Proficiency. Second Edition (BOT-2). Minneapolis: AGS Publishing; 2006
21. Kiphard EJ, Schilling F. Körperkoordinationstest für Kinder. Überarbeitete und ergänzte Auflage. Beltz Test GmbH: Göttingen. Germany; 2007 [in German]
22. Prätorius B, Milani TL. Motorische Leistungsfähigkeit bei Kindern: Koordinations- und Gleichgewichtsfähigkeit: Untersuchung des Leistungsgefälles zwischen Kindern mit verschiedenen Sozialisationsbedingungen. Deutsche Zeitschrift für Sportmedizin 2004; 55(7/8): 172-176 [in German]
23. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale: NJ Erlbaum; 1988
24. Chiodo S, Tessitore A, Cortis C et al. Effects of official Taekwondo competitions on all-out performances of elite athletes. J Strength Cond Res 2011.;25(2): 334-349
25. Claessens A, Beunen G, Wellens R et al. Somatotype and Body Structure of World Top Judoists. J Sports Med Phys Fitness 1987; 27(1): 105-113
26. Lech G, Tyka A, Pałka T et al. Effect of physical endurance on fighting and the level of sports performance in junior judokas. Arch Budo 2010. 6(1): 1-6
27. Sadowski J, Gierczuk D, Miller J et al. Success factors in elite WTF taekwondo competitors. Arch Budo 2012. 8(3): 141-146

28. Sadowski J. Dominant Coordination Motor Abilities in Combat Sports. J Hum Kinet 2005; 13: 61-72
29. Gulbin JP, Croser MJ, Morley EJ et al. An integrated framework for the optimisation of sport and athlete development: a practitioner approach. J Sports Sci 2013; 31(12): 1319-1331
30. Régnier G, Salmela JH, Russell SJ. Talent detection and development in sport. In: Singer RN, Murphy M, Tennant LK, eds. Handbook of research on sport psychology. New York: Macmillan Publishing Company, 1993: 290-313

Iets met gemak doen wat anderen moeilijk vinden heet talent.

Doen wat enkel talent niet lukt, heet genialiteit.

(Henry Frederic Amiel, filosoof)

2.3 PREDICTING PERFORMANCE AND SURVIVAL IN SPORTS

2.3.1 PAPER 4: STATURE AND JUMPING HEIGHT ARE REQUIRED IN FEMALE VOLLEYBALL, BUT MOTOR COORDINATION IS A KEY FACTOR FOR FUTURE ELITE SUCCESS.

the Journal of Strength and Conditioning Research™
THE OFFICIAL RESEARCH JOURNAL OF THE NATIONAL STRENGTH AND CONDITIONING ASSOCIATION
NSCA NATIONAL STRENGTH AND CONDITIONING ASSOCIATION

Johan Pion*, Job Fransen*, Dieter Deprez, Veerle Segers, Roel Vaeyens, Renaat Philippaerts and Matthieu Lenoir

(Johan Pion and Job Fransen share first authorship)

2015

Journal of Strength and Conditioning Research

29(6), p. 1480 - 1485

Abstract

It was hypothesized that differences in anthropometry, physical performance and motor coordination would be found between Belgian elite and sub-elite level female volleyball players using a retrospective analysis of test results gathered over a five-year period. The test sample in this study consisted of 21 young female volleyball players (15.3 ± 1.5 y) who were selected to train at the Flemish elite sport schools for Volleyball in 2008. All players (elite n = 13; sub-elite n = 8) were included in the same talent development program and the elite-level athletes were of a high to very high performance levels according European competition level in 2013. Five multivariate analyses of variance (MANOVA) were used. There was no significant effect of playing level on measures of anthropometry (F = 0.455, p = 0.718, η_p^2 = 0.07), flexibility (F = 1.861, p = 0.188, η_p^2 = 0.19), strength (F = 1.218, p = 0.355, η_p^2 = 0.32); and speed and agility (F = 1.176, p = 0.350, η_p^2 = 0.18). MANOVA revealed significant multivariate effects between playing levels for motor coordination (F=3.470, p = 0.036, η_p^2 = 0.59). A Mann-Whitney U-test and a sequential discriminant analysis confirmed these results. Previous research revealed that stature and jump height are prerequisites for talent identification in female volleyball. In addition, the results show that motor coordination is an important factor in determining inclusion into the elite level in female volleyball.

Introduction

Volleyball is an Olympic team sport played by two teams of six players trying to ground the ball in the opposition's playing area by blocking and spiking the ball over a net that separates both playing areas. Stature and jumping ability are generally considered as the key characteristics of the successful volleyball player, in males as well as females (14, 20). Previous research has shown that youth volleyball players are on average taller than athletes from other sports like handball (2), skating, swimming, and tennis (11). Within the population of volleyball players, length has been associated with expertise level (9, 21) For example, Gabett et al. (9) showed that anthropometric characteristics are useful to discriminate between playing level in national, state and novice Australian female and male players. Furthermore, Stamm et al. (23) showed that 13-16 year old female volleyball players who are proficient at spiking, blocking and attacking, were on average taller and heavier than their less proficient peers. These findings show that being tall is an important performance related characteristic for female volleyball. Therefore, it is important for any test battery used in female volleyball to include anthropometric measures.

Besides anthropometrical parameters several physical attributes related to performance in female volleyball players have been identified, including shoulder flexibility and strength (16). Other research studies on physical performance measures that distinguish between female volleyball players' level of performance included differences in vertical jump height (8, 9, 21), spiking and blocking height (22), estimated VO2 max (9, 22), 20m sprint times (22) and 150 yard anaerobic shuttle run time (21). Ziv and Lidor (27) and Lidor and Ziv (14) expanded on the subject of physical performance attributes of volleyball players with a review of observational and experimental studies of vertical jump in male and female volleyball players (27) and later with a review of physical and physiological attributes of adolescent volleyball players (14). They concluded that female players with a higher skill level perform better on the vertical jump test than players from lower playing levels, and that this between-level difference increases with age.

Elite volleyball players not only possess anthropometric qualities and physical abilities exceeding less talented players; they also show higher motor skill levels. Stamm et al. (23) reported that basic volleyball skills, such as blocking, spiking, and feinting, are related to an adolescent volleyball players' success. Additionally, Katic and colleagues (11) showed a positive relationship between skill execution and player ranking in adolescent female players. These findings demonstrate that high skill levels and general motor coordination are indeed performance-related factors affecting success during female volleyball competition. An elite player possesses optimal balance control in static and dynamic conditions [5,6], and the ability to move in a controlled way over the limited playing surface. Such general motor coordination has also been associated with competition performance in other sports (26).

In spite of this body of information on performance-related characteristics in elite volleyball players, studies that relate these characteristics to performance from a longitudinal perspective are very rare. To date, we are aware of no studies that have related initial test results with subsequent performance classifications after several years of competition. In another skill-based sport, Vandorpe et al. (25) showed that motor coordination was the most discriminating factor between expert and non-expert female gymnasts, and that competitive performance in a selected group could be best predicted from a general coordination test they underwent two years before the competition. This motor coordination was considered as a good estimation of the potential, i.e. the progress these gymnasts were supposed to make in these two years.

The current study used a retrospective analysis of test results five years in the past to assess differences in anthropometry, physical performance and motor coordination between Belgian elite and sub-elite level female volleyball players. It was hypothesized that differences in anthropometry, physical performance and general motor coordination assessed five years prior could predict athletes' current playing levels.

Methods

Participants and design

Since 1998, 213 female players who were selected to train at the Flemish elite sport schools for Volleyball were tested every trimester to assess their development. The test sample in this study consisted of 21 young female volleyball players (15.3 ± 1.5 y). This sample was subdivided into players that made it to an elite level (Belgian National Team or Belgian First division champions during the 2012-2013 season; n = 13) or players classified as sub-elite (not in the Belgian National Team and playing in any other first division team than the championship team; n = 8). The Belgian female volleyball team currently holds the 22nd spot in the world ranking according to the Fédération Internationale de Volleyball and finished in third place in the 2013 European Championships in Germany and Switzerland. Therefore, the athletes evaluated in this study could be classified as having a high to very high skill level according to European standards. Written informed consent was obtained from all participants and their parent(s) or guardian(s) and the study received approval from the local ethics committee.

Measurements

Anthropometric, physical, and motor coordination characteristics (25) were assessed by trained test supervisors on a sports surface in an indoor sports hall. The athletes performed all tests barefoot except the sprints and counter movement jump which were performed while wearing running shoes.

Anthropometry and body composition testing consisted of height (Harpenden, portable Stadiometer, Holtain, UK), sitting height (Harpenden, sitting table, Holtain, UK), body weight, and body fat measurements (Total body composition analyser, TANITA BC-420SMA, Japan).

Flexibility was assessed by the sit-and-reach test (SAR), according to the guidelines of the council of Europe (6) and by a shoulder rotation test (15). A handgrip dynamometer was used to assess hand grip strength (HGR) (6). Upper body strength endurance was measured by knee push-ups (KPU) and sit-ups test (SUP), according to the Bruininks-Oseretzky Test of Motor Proficiency (BOT-2) (4) procedures. To assess explosive lower limb power, counter movement jump (CMJ) (3) and standing broad jump (SBJ) (6) tests were used. Speed and agility were assessed by the EUROFIT 10 x 5 m shuttle run test (6) and two maximal sprints of 30 m with a split time at 5 m (MicroGate Racetime2 chronometry and Polifemo Light photocells, Microgate, Italy). The recovery time between sprints was set at 2 min.

Motor coordination was evaluated by means of three subtests of the KörperkoordinationsTest für Kinder (12): (1) backward balance: walking backwards along balance beams of decreasing width (6 cm, 4.5 cm and 3 cm respectively); (2) jumping sideways: two-legged jumping sideways over a wooden slat for 15 seconds; (3) moving sideways: moving sideways on wooden platforms for 20 seconds. Test items for the KTK have a test-retest reliability of 0.80 ≤ r ≤ 0.95 (12). Additionally, validity and reliability of the KTK in female adolescent athletes has been found to be very good (10, 18). A detailed description of these tests is available in Vandorpe et al. (25). The fourth test of the KTK was excluded due to the risk of ankle sprain (19). To assess hand-dribbling performance, the UGent Dribbling Test (24) was used. This test consists of a maximal slalom sprint of 18.33 m while hand-dribbling a volleyball on a carpet designed specifically for the Flemish Sports Compass, a test battery developed to investigate the differences between sports based on generic talent characteristics used in 16 different sports in the Flemish elite sport schools. The time to complete the hand-dribbling test was measured using a stopwatch. Test-retest reliability for the UGent hand-dribbling test was ICC = 0.95 (18, 24). Finally, the overhead-throwing test with a badminton shuttle, also from the FSC, was used in order to evaluate over-arm throwing competency (17). The goal of this test was to throw the shuttle as far and accurately (straight forward) as possible, holding the shuttle between thumb and index finger. Throwing a shuttle requires less strength than throwing coordination. The summed throwing distance of five trials was recorded (ICC = 0.82).

Data Analysis

All data were analysed using SPSS for windows (version 19). Five multivariate analyses of variance (MANOVA's) were used to analyse differences in anthropometry, flexibility, strength, speed and agility and motor coordination between elite and sub-elite players with playing level as a fixed factor. In addition, the magnitude of the differences between the levels was estimated using Partial Eta Squared (η_p^2) with cut-off scores of 0.01 (small), 0.06 (moderate) and 0.14 (large) (5) The level of significance was set at $p<0.05$. To confirm the statistical effects, which are simply due to outliers or non-normal distributions, a non-parametric Mann-Whitney U-test was added. Furthermore a sequential discriminant analysis was used to subdivide the sample just on the basis of the coordination tests scores. In this analysis the coordination test scores were entered as independent variables. The classification results indicate the correctly and not correctly classified athletes. Athletes classified as elite even though they are non-elite are classified false positive and the non-elite players classified as elite volleyball players are classified false negative.

Results

Using MANOVA, there was no significant effect of playing level on measures of anthropometry ($F = 0.455$, $p = 0.718$, $\eta_p^2 = 0.07$), flexibility ($F = 1.861$, $p = 0.188$, $\eta_p^2 = 0.19$), strength ($F = 1.218$, $p = 0.355$, $\eta_p^2 = 0.32$); and speed and agility ($F = 1.176$, $p = 0.350$, $\eta_p^2 = 0.18$). MANOVA revealed significant multivariate effects between playing levels for motor coordination ($F=3.470$, $p = 0.036$, $\eta_p^2 = 0.59$). Univariate analysis for motor coordination test scores revealed differences between playing levels for backward balance ($F = 15.131$, $p = 0.001$, $\eta_p^2 = 0.49$), jumping sideways ($F = 6.304$, $p = 0.023$, $\eta_p^2 = 0.28$) and moving sideways ($F = 6.869$, $p = 0.019$, $\eta_p^2 = 0.30$) in favour of the elite level players. No significant differences between playing levels were found for shuttle throw ($F = 0.740$, $p = 0.402$, $\eta_p^2 = 0.04$) and dribble hands ($F = 3.513$, $p = 0.079$, $\eta_p^2 = 0.18$). Means (SD), F-, p-values and effect sizes (η_p^2) for the five MANOVA's are presented in Table 16.

Table 16: Mean (SD) from MANOVAs for elite and sub-elite female volleyball players with corresponding F-values, p-values and effect sizes for anthropometry, flexibility, strength, speed and agility, and motor coordination.

	n	Elite	n	Sub-elite	F-value	p-value	Effect Size
Age (years)	13	15.4 (1.6)	8	15.1 (1.4)	0.526	0.605	0.24
Anthropometry	***13***		8				
MANOVA Anthropometry					**0.455**	**0.718**	**0.07**
Body Height (cm)		176.8 (8.2)		177.4 (7.3)			
Body Weight (kg)		64.4 (7.6)		65.5 (8.3)			
Body Fat (%)		21.8 (5.1)		24.0 (5.5)			
Flexibility	***12***		7				
MANOVA flexibility					**1.861**	**0.188**	**0.19**
Shoulder Flexibility (cm)		83.6 (14.6)		97.7 (21.7)			
Sit and Reach (cm)		32.8 (6.5)		27.4 (6.7)			
Strength	***11***		***8***				
MANOVA Strength					**1.218**	**0.355**	**0.32**
Hand Grip (kg)		36.7 (4.9)		35.3 (6.7)			
Knee Push Ups (n/30s)		27.9 (3.7)		31.9 (3.8)			
Sit-ups (n/30s)		45.1 (6.4)		42.3 (4.1)			
Standing Broad Jump (cm)		209.9 (16.0)		197.9 (18.7)			
Counter Movement Jump (cm)		34.5 (3.6)		31.1 (3.1)			
Speed and Agility	***13***		***7***				
MANOVA Speed and Agility					**1.176**	**0.350**	**0.18**
Shuttle Run (s)		18.8 (1.1)		19.2 (0.7)			
Sprint 5m (s)		1.20 (0.09)		1.26 (0.07)			
Sprint 30m (s)		4.91 (0.24)		5.05 (0.26)			
Motor Coordination	***12***		***6***				
MANOVA Motor Coordination					**3.470**	**0.036**	**0.59**
Balancing Backwards (points)		63 (8)		48 (7)	15.131	0.001	0.49
Jumping Sideways (points)		93 (8)		84 (5)	6.304	0.023	0.28
Moving Sideways (points)		66 (7)		56 (8)	6.869	0.019	0.30
Dribble Hands (s)		16.0 (1.6)		17.6 (1.8)	3.513	0.079	0.18
Shuttle Throw (m)		32.3 (2.6)		33.4 (2.6)	0.740	0.402	0.04

To confirm the results of the MANOVAs a Mann-Whitney U-test rejected the null hypothesis for two strength tests i.e. knee push-ups (p =0.033) and counter movement jump (p = 0.037) and three motor coordination tests, backward balance (p = 0.006), jumping sideways (p = 0.008) and moving sideways (, p = 0.003).

Table 17: Mean (SD) from Mann-Whitney U-test for elite and sub-elite female volleyball players with corresponding p-values.

	n	Elite	n	Sub-elite	p-value
Age (years)	13	15.4 (1.6)	8	15.1 (1.4)	0.645
Anthropometry	***13***		8		
Body Height (m)		1.768 (0.082)		1.774 (0.073)	1.000
Body Weight (kg)		64.4 (7.6)		65.5 (8.3)	0.750
Body Fat (%)		21.8 (5.1)		24.0 (5.5)	0.210
Flexibility	***12***		7		
Shoulder Flexibility (m)		0.836 (0.146)		0.977 (0.217)	0.068
Sit and Reach (m)		0.328 (0.065)		0.274 (0.067)	0.121
Strength	***11***		***8***		
Hand Grip (kg)		36.7 (4.9)		35.3 (6.7)	0.268
Knee Push Ups (n/30s)		27.9 (3.7)		31.9 (3.8)	0.033
Sit-ups (n/30s)		45.1 (6.4)		42.3 (4.1)	0.374
Standing Broad Jump (m)		2.099 (0.160)		1.979 (0.187)	0.140
Counter Movement Jump (m)		0.345 (0.036)		0.311 (0.031)	0.037
Speed and Agility	***13***		***7***		
Shuttle Run (s)		18.8 (1.1)		19.2 (0.7)	0.238
Sprint 5m (s)		1.20 (0.09)		1.26 (0.07)	0.135
Sprint 30m (s)		4.91 (0.24)		5.05 (0.26)	0.183
Motor Coordination	***12***		***6***		
Balancing Backwards (points)		63 (8)		48 (7)	0.006
Jumping Sideways (points)		93 (8)		84 (5)	0.008
Moving Sideways (points)		66 (7)		56 (8)	0.003
Dribble Hands (s)		16.0 (1.6)		17.6 (1.8)	0.104
Shuttle Throw (m)		32.3 (2.6)		33.4 (2.6)	0.432

A sequential discriminant analysis using the three significant motor coordination tests accounted for an 85.0% correct identification of basketball players (r_{can} =0.750 and Wilks' Λ =0.473 and P <0.003). Two players were classified as false positive and one player as false negative.

Discussion

The present retrospective study used anthropometry, physical performance and motor coordination scores, assessed five years prior to examine differences between current international elite and sub-elite female volleyball players. The main findings were that current high-level players had better motor coordination compared with average-level players. It was expected that elite players, however, would have different anthropometrical, physical performance and motor coordination scores than sub-elites. This study reveals that only motor coordination scores were different between both playing levels. This might be due to the homogeneity of the group studied because all talented volleyball players had been pre-selected for top-sports academies based on their stature and physical performance, as is the practice in soccer (7) or artistic gymnastics (26).

A study by Barnes et al. (1) reported a greater jump height. The fact that vertical jumping height is an important performance characteristic for volleyball players is not surprising as it can be used when blocking and spiking the ball during the game. However, according to a systematic review by Lidor and Ziv (14), information on whether winning teams possess better average vertical jumping heights compared to losing teams is not conclusive.

Our finding that differences among playing levels were dependent on motor coordination is somewhat in accordance with a study in gymnastics by Vandorpe and colleagues (25) where motor coordination was the most discriminating factor between high and low level female gymnasts. The authors in this study classified gymnastics as a skill-based sport that requires an athlete to possess high levels of motor coordination (control, balance, speed of movement, etc.) in order to be successful. Because of the speed of the game (the speed of a volleyball serve or spike in female volleyball can reach up to 100 km/h) and the three-touch rule that requires excellent technique, volleyball can also be considered a skill-based sport, which requires well-developed motor coordination levels. This argument is further supported by the fact that volleyball not only incorporates complex actions like passing or spiking, it also requires that these actions be coupled with body control and agility as the players efficiently reposition themselves between ball contacts.

In conclusion, the results from this study show that motor coordination might be an important factor in determining who makes it into an expert level in female volleyball and who does not. These findings support the idea that general motor coordination might be a valuable indicator of an athlete’s potential for progression in skill-based sports like volleyball as was already documented in artistic gymnastics (26). Therefore, talent identification programs in female volleyball should besides screening for body height and jumps, include motor coordination testing to assure for optimal performance screening. The strengths of this study include the use of retrospective analyses of anthropometry, physical fitness and motor coordination based on current playing level, the fact that all players were included in the same talent development program and hence the overall high level of performance within the test sample. The limitation of a relatively small sample size is inherent to research in elite athletes, who are not numerous by definition. Future research should adopt a similar approach to investigate differences between performance levels in other sports in order to further document the value of general, non sport-specific motor coordination in talent identification.

Practical applications

The results of this study may have practical applications for talent identification in female volleyball. Differences in anthropometry, physical performance and general motor coordination assessed five years prior could predict athletes' current playing levels. Therefore, it is recommended that talent identification programs in female volleyball should besides screening for body height and jumps, include motor coordination testing to assure for a broader performance screening. Krauss and colleagues (13) reported that functional movement screening showed an improvement on general motor quality. It seems that additional motor coordination tests identify the ‘better movers’ and provide more insights to the coaches on the potential of volleyball players.

References

1. Barnes JL, Schilling BK, Falvo MJ, Weiss LW, Creasy AK, and Fry AC. Relationship of jumping and agility performance in female volleyball athletes. *J Strength Cond Res* 21: 1192-1196, 2007.
2. Bayios IA, Bergeles NK, Apostolidis NG, Noutsos KS, and Koskolou MD. Anthropometric, body composition and somatotype differences of Greek elite female basketball, volleyball and handball players. *J Sport Med Phys Fit* 46: 271-280, 2006.
3. Bosco C, Luhtanen P, and Komi PV. A Simple Method for Measurement of Mechanical Power in Jumping. *European journal of applied physiology and occupational physiology* 50: 273-282, 1983.
4. 4. Bruininks RH and Bruininks BD. *BOT-2: Bruininks-Oseretsky Tests of Motor Proficiency.* Minneapolis: AGS Publishing, 2006.
5. Cohen J. *Statistical power analysis for the behavioral sciences* Hillsdale: NJ Erlbaum, 1988.
6. Council of Europe. *Eurofit: Handbook for the EUROFIT Tests of Physical Fitness.* Rome: Secretariat of the Committee for the Development of Sport within the Council of Europe, 1988.
7. Deprez D, Coutts AJ, Fransen J, Deconinck F, Lenoir M, Vaeyens R, and Philippaerts R. Relative Age, Biological Maturation and Anaerobic Characteristics in Elite Youth Soccer Players. *Int J Sports Med* 34: 897-903, 2013.
8. Fleck SJ, Case S, Puhl J, and Van Handle P. Physical and physiological characteristics of elite women volleyball players. *Can J Appl Sport Sci* 10: 122-126, 1985.
9. Gabbett T and Georgieff B. Physiological and anthropometric characteristics of australian junior national, state,and novice volleyball players. *J Strength Cond Res* 21: 902-908, 2007.
10. Hesar GZ. Effect of menstrual cycle and identification of intrinsic risk factors for lower leg injuries, in: *Faculty of Medicine and Health Sciences*. Ghent Ghent University, 2011.
11. Katic R, Grgantov Z, and Jurko D. Motor structures in female volleyball players aged 14-17 according to technique quality and performance. *Collegium Antropol* 30: 103-112, 2006.
12. Kiphard EJ and Schilling F. *Körperkoordinationstest für Kinder.* Weinheim: Beltz: Test GmbH., 2007.
13. Kraus K, Schutz E, Taylor WR, and Doyscher R. Efficacy of the Functional Movement Screen: A review. *J Strength Cond Res*, 2014.
14. Lidor R and Ziv G. Physical and Physiological Attributes of Female Volleyball Players-a Review. *J Strength Cond Res* 24: 1963-1973, 2010.
15. Matthys SP, Vaeyens R, Coelho ESMJ, Lenoir M, and Philippaerts R. The contribution of growth and maturation in the functional capacity and skill performance of male adolescent handball players. *Int J Sports Med* 33: 543-549, 2012.
16. Melrose DR, Spaniol FJ, Bohling ME, and Bonnette RA. Physiological and performance characteristics of adolescent club volleyball players. *J Strength Cond Res* 21: 481-486, 2007.
17. Mohamed H, Vaeyens R, Matthys S, Multael M, Lefevre J, Lenoir M, and Philippaerts R. Anthropometric and performance measures for the development of a talent detection and identification model in youth handball. *J Sport Sci* 27: 257-266, 2009.
18. Pion J, Segers V, Fransen J, Debuyck G, Deprez D, Haerens L, Vaeyens R, Philippaerts R, and Lenoir M. Generic anthropometric and performance characteristics among elite adolescent boys in nine different sports. *Eur J Sport Sci*: 1-10, 2014.
19. Prätorius B and Milani TL. Motorische Leistungsfâhigkeit bei Kindern: Koordinations- und Gleichgewichtsfâhigkeit: Untersuchung des Leistungsgefälles zwischen Kindern mit verschiedenen Sozialisationsbedingungen. *Deutsche Zeitschrift fuer Sportmedizin* 55: 172-176, 2004.
20. Rikberg A and Raudsepp L. Multidimensional Performance Characteristics in Talented Male Youth Volleyball Players. *Pediatr Exerc Sci* 23: 537-548, 2011.
21. Schaal M, Ransdell LB, Simonson SR, and Gao Y. Physiologic Performance Test Differences in Female Volleyball Athletes by Competition Level and Player Position. *J Strength Cond Res* 27: 1841-1850, 2013.
22. Smith DJ, Roberts D, and Watson B. Physical, physiological and performance differences between canadian national team and universiade volleyball players. *J Sport Sci* 10: 131-138, 1992.
23. Stamm R, Stamm M, and Thomson K. Role of adolescent female volleyball players' psychophysiological properties and body build in performance of different elements of the game. *Percept Mot Skills* 101: 108-120, 2005.

24. Vandendriessche JB, Vaeyens R, Vandorpe B, Lenoir M, Lefevre J, and Philippaerts RM. Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years). *J Sport Sci* 30: 1695-1703, 2012.
25. Vandorpe B, Vandendriessche J, Vaeyens R, Pion J, Lefevre J, Philippaerts R, and Lenoir M. Factors Discriminating Gymnasts by Competitive Level. *Int J Sports Med* 32: 591-597, 2011.
26. Vandorpe B, Vandendriessche JB, Vaeyens R, Pion J, Lefevre J, Philippaerts RM, and Lenoir M. The value of a non-sport-specific motor test battery in predicting performance in young female gymnasts. *J Sport Sci* 30: 497-505, 2012.
27. Ziv G and Lidor R. Physical characteristics, physiological attributes, and on-court performances of handball players: A review. *Eur J Sport Sci* 9: 375-386, 2009.

Door ongebaande sneeuw te gaan,

hoe lustig is’t,

hoe leutig!

(Guido Gezelle)

2.3.2 PAPER 5: TALENT IN FEMALE GYMNASTICS: A SURVIVAL ANALYSIS BASED UPON PERFORMANCE CHARACTERISTICS

Pion J, Lenoir M, Vandorpe B, Segers V

International Journal of Sports Medicine,

2015

Volume 36, p. 935 -940

Abstract

This study investigated the link between the anthropometric, physical and motor characteristics assessed during talent identification and dropout in young female gymnasts. Three cohorts of female gymnasts (n=243; 6-9 y) completed a test battery for talent identification. Performance-levels were monitored over five years of competition. Kaplan-Meier and Cox Proportional Hazards analyses were conducted to determine the survival rate and the characteristics that influence dropout respectively. Kaplan-Meier analysis indicated that only 18% of the female gymnasts that passed the baseline talent identification test survived at the highest competition level five years later. The Cox Proportional Hazards Model indicated that gymnasts with a score in the best quartile for a specific characteristic significantly increased chances of survival by 45% to 129%. These characteristics being: basic motor skills (129%), shoulder strength (96%), leg strength (53%) and three gross motor coordination items (45% to 73%). These results suggest that tests batteries commonly used for talent identification in young female gymnasts may also provide valuable insights into future dropout. Therefore, multidimensional test batteries deserve a prominent place in the selection process. The individual test results should encourage trainers to invest in an early development of basic physical and motor characteristics to prevent attrition.

Introduction

International success in gymnastics requires many hours of dedicated practice [11]. Russell and colleagues [22] indicate that 8 to10 years of preparation is necessary to reach the elite-level in sports. Given that peak performance in female gymnastics is usually reached at the age of 16, a significant amount of deliberate practice is required from a young age, usually commencing around the age of 6. Beside the issue of early specialization in gymnastics, the process of talent identification and development is crucial.

Indeed, research has revealed that multi-dimensional test batteries may be useful to identify talent. A longitudinal study conducted by Prescott examined the identification and development of talent within a mixed ability sample of 48 gymnasts [21]. In this study, potentially prognostic talent characteristics from social-demographic, physical, perceptual-motor and psychological dimensions of performance were assessed in an "initial" measurement session. Performance was assessed 17 months later using a composite index of competitive performance and technical skill acquisition scores. The results indicated that the profile of the young female gymnast is multidimensional. Prescott recommended that information should be analyzed within each dimension of performance before being combined to produce a multi dimensional profile [21]. The physical characteristics were found to be the most prognostic indicators of talent and were recommended for inclusion in both the initial and subsequent monitoring processes. The significant relationship between several anthropometric variables and gymnastic performance are however insufficiently high to predict performance scores on an individual basis.

More recently, Vandorpe and colleagues [26] examined the effectiveness of a multi-dimensional test battery with a combination of anthropometric, physical, coordinative and technical field tests to predict performance level two years later. They showed that a combination of anthropometric, physical and coordination tests predicts the future level of performance two years later, with coordination playing the largest part in this prediction. In gymnastics it is important that talent is identified early in the career of the athlete, and therefore a good understanding of the factors influencing the development of the gymnasts is essential. While drop out can be considered as an almost natural selection mechanism in elite sports, research efforts on this topic have mainly focused on psychological aspects and causes of drop out [12,13,27]. According to Petlichkoff, two-thirds of the athletes between 7-18 years withdraw from sports participation each year [20]. Negative experiences such as lack of fun, coach conflicts and lack of playing time are identified as primary causes of dropout [12,13,27]. However, we do not know to what extent physical and motor competence plays a part in the decision to quit sports practice. Butcher et al. recognized that the reasons for dropout at least partially depend on the level and intensity of previous sports participation [6]. An insufficient level of essential anthropometric, physical and coordination characteristics might lead to an early levelling off of the progression curve, leading to the decision to quit a specific sport.

However, there is a lack of studies investigating attrition in female gymnastics based on anthropometric, physical and motor coordination characteristics. One previous investigation, however not related to attrition, found a correlation between anthropometric variables and gymnastic performance of 168 female gymnasts (16.5y. ± 1.8y.), participating at the 1987 World championships [8]. A combination of anthropometric dimensions predicted 32% – 45% of the variance in performance. Claesssens and Lefevre also investigated morphological and performance characteristics as dropout indicators in a sample of younger competitive female gymnasts (10.5y. ± 2.6y.). The primary finding was that 'surviving' female competitive gymnasts were smaller, with a lower body weight, a lower value of subcutaneous fat, narrower hips and broader shoulders than their counterparts. It has also been shown that flexibility, strength and anaerobic endurance are important talent characteristics for delivering good performances [7].

While multi-dimensional test batteries are important for talent identification, they may also be useful for identifying dropout. However, there is a lack of research investigating the link between factors identified in the test batteries and dropout. Therefore the purposes of the present longitudinal study were threefold. First, to compare anthropometric, physical and motor coordination characteristics between gymnasts continuing at a high level and gymnasts dropping out from competition 3, 4 and 5 years after the baseline measurement. Second, to establish the discriminative power for dropout in female gymnastics, using the multidimensional test battery designed by Vandorpe et al. [25]. Finally, to investigate the predictive power of dropout based on critical talent characteristics.

Methods

In this retrospective study young female gymnasts (6-9 y) completed a gymnastics test battery for talent identification. Performance-levels were monitored over five years of subsequent competition. The results presented in this study are derived from a large investigation examining a total of 756 gymnasts from 81 gymnastics clubs at the highest level (A level). In Flanders gymnasts can compete in three competition levels A or I (under 9y), B and C. The larger investigation tested seven separate cohorts of gymnasts over seven years (2008-2014). This study presents the data from three separate cohorts (2008-2010) resulting in a total sample of 243 female gymnasts (7.7 ± 0.7 y). Flanders GymFed invited the clubs to delegate their best gymnasts, so the participants in the baseline measurement in this study are already a selected group. The participants trained 9.5 ± 2.5 hours a week, in the past 2.8 ± 1.4 year. Including only these three cohorts allows for five years of retrospective analysis (supplemental material 1). This study was also part of a broader project (Flemish Sports Compass) that investigated the physical and general coordinative characteristics of Flemish children. The project was conducted in accordance with recognised ethical standards [14] and was approved by the Ethics Committee of the Ghent University Hospital. Written informed parental consent was obtained for all participants

The anthropometric assessments were conducted following standardized protocols [18]. Height was measured using a portable stadiometer to the nearest 0.1 cm (Harpenden, Holtain Ltd., Crymych, UK). Body mass (to the nearest 0.1 kg) and body fat (to the nearest 0.1%) were determined by means of a bioelectrical impedance scale (TANITA BC-420SMA, Weda B.V., Naarden, Holland). Height and weight values were used to calculate Body mass Index. *Bi-acromial diameter and bi-iliocristal diameter (to the nearest 0.1 cm) were measured with a sliding caliper (Holtain, UK) and both measurements were used to calculate the androgyny index (Tanner index = 3x bi-acromial diameter – bi-iliocristal diameter).*

Flexibility was assessed (to the nearest 0.1 cm) using the sit-and-reach test of the Eurofit test battery [10]. Explosive leg power was evaluated with the countermovement jump (0.1 cm), performed with hands on hips, using Optojump (Microgate, Bolzano, Italy) (Cometti & Cometti, 2007). The knee push-ups and sit-ups tests, following the Bruininks-Oseretsky test of Motor Proficiency-2 procedures [5] were used to assess upper body strength and core stability. Sprinting ability was measured using a 20 m test with sprint times being recorded using Polifemo light photocells with 0.001 s accuracy (Racetime2, Microgate, Bolzano, Italy) [17]. Anaerobic performance was assessed with a one-minute rope jumping test [25].

The KörperkoordinationsTest für Kinder (KTK) [15] is a widely used, valid, and reliable instrument for assessing the general motor coordination of children [2,19,25]. The KTK consists of four subtests: (1) KTKBB walking backwards three times along each of three balance beams of decreasing width, with a possible maximum score of 72; (2) KTKMS moving sideways on wooden platforms in 20 s with the score being the sum of the number of relocations over two trials; (3) KTKJS jumping sideways with two feet over a wooden slat for 15 s, with the score being the sum of the number of jumps over two trials; and (4) KTKHH hopping for height on one leg over a foam obstacle increasing in height by 5 cm at each step, with a possible maximum score of 78. The raw performance scores of each subtest are transformed into age- and gender-specific motor quotients, together resulting in a general motor quotient (MQKTK). Nine additional basic tests (running backwards, skipping, hopping, shuffle pass, cross steps, bouncing, jumping jacks, tuck jumps, and giant jumps) were judged on a 10-item qualitative scale (i.e. ability to perform the movement, without falling, with a steady rhythm, supported by arm movements, balanced, with confidence, dynamic, without sloppiness, with sufficient amplitude, and seemingly effortless) to determine the basic locomotion skills of the gymnasts, with a possible maximum score of 90. Trained coaches judged these items, and reliability coefficients were high (test–retest 0.94, inter-rater reliability 0.93) [25].

First, descriptive statistics were studied with the threshold and mean scores that were needed to continue gymnastics 3, 4 or 5 years after the entry test was conducted. Second, to establish the discriminative power for dropout in female gymnastics after 3, 4 and 5 years of practice a discriminant analysis was used to investigate the relevant performance measurements ((Table 20). The grouping variable was continuing or discontinuing gymnastics and the independent variables were the test results obtained from the five anthropometrical, six physical and six motor coordination characteristics. The classification results indicate the correctly and incorrectly classified gymnasts. Gymnasts classified as 'survivors' despite dropping out were classified as false positive and gymnasts wrongly classified, as dropouts were considered as false negative. Third, a Survival Analysis [23] was applied to predict the dropout based on the Quartile scores from the different performance characteristics. Kaplan – Meier analysis was used to investigate the dropout rate and the mean survival time. Cox Regression survival analysis confirmed the significant performance characteristics and predicted the hazard ratios for dropout in female gymnastics $_{1-}$.

Results

Descriptive statistics revealed that the threshold scores for the survivors increased year after year. For example the lowest sit and reach score required for the gymnasts to continue at the highest level was 25.5 cm, 29.0 cm and 31.0 cm, at 3, 4 and 5 years post baseline respectively. This suggests that the baseline results are more exigent for each year that gymnasts continue their sport. Therefore a gradual raise of the threshold scores might be designated to include the possibility of compensating for some of the talent characteristics.

The second analysis aimed to discriminate between gymnasts continuing or discontinuing their sport at the highest competition level (A-level). There was a 68.7% correct classification 3 years after testing the female gymnasts. From the 138 survivors and 110 dropouts, 34 gymnasts were classified false positive and 42 false negative (r_{can} =0.452 and Wilks' Λ =0.796 and P <0.001). The gymnasts that discontinued their sport had significantly lower scores for sit and reach; 20-m sprint; knee push-ups; rope skipping; basic skills; MQKTK; KTKMS and KTKHH. After 4 years a 79.4% correct classification was reported by the discriminant analysis. From the remaining 67 survivors and 176 gymnasts, discontinuing their sport, 15 were classified false positive and 35 false negative (r_{can} =0.486 and Wilks' Λ =0.763 and P <0.001). The gymnasts that discontinued their sport had significantly lower scores for sit and reach; 20-m sprint; knee push-ups; sit-ups; rope skipping; basic skills; MQKTK; KTKBB; KTKJS; KTKMS and KTKHH. Five years after the baseline test 87.7% of the gymnasts were correctly classified. Only 35 gymnasts "survived" and remain competitive at the highest level. A total of 208 peers dropped out; 3 were false negative gymnasts continuing and 27 false positive gymnasts discontinuing gymnastics (r_{can} =0.419 and Wilks' Λ =0.824 and P <0.001). The discontinuing gymnasts had significantly lower scores for 20-m sprint; counter movement jump; knee push-ups; sit-ups; rope skipping; basic skills; KTKJS and KTKHH. The classification rates, i.e. the percentage of correctly classified gymnasts, increase for each additional year the gymnasts continue or discontinue their sport after the initial testing (Table 18).

Table 18: Discriminant analysis 3, 4 and 5 years post entry test, with F-values and correctly classified gymnasts based on the 17 tests and measurements (full model).

	3y post entry test	4y post entry test	5y post entry test
Anthropometry			
height	F = 0.003	F = 0.012	F = 0.406
mass	F = 0.031	F = 0.115	F = 0.004
BMI	F = 0.154	F = 0.184	F = 0.674
fat %	F = 0.425	F = 0.238	F = 0.739
tanner index	F = 0.053	F = 0.029	F = 0.001
Physical Characteristics			
sit and reach	F = 8.882 **	F = 6.130 *	F = 0.519
sprint 20 m	F = 6.579 *	F = 7.891 **	F = 8.172 **
counter movement jump	F = 0.575	F = 4.170 *	F = 11.348 **
knee push-ups	F = 15.583 **	F = 12.451 **	F = 10.567 **
sit-ups	F = 2.055	F = 3.919 *	F = 14.574 **
rope skipping 60 s	F = 4.684 *	F = 5.420 *	F = 6.343 *
Motor Coordination			
KTK balance beam	F = 3.400	F = 6.266 *	F = 3.055
KTK jumping sideways	F = 3.816	F = 4.251 *	F = 5.748 *
KTK moving sideways	F = 6.775 *	F = 11.942 **	F = 0.054
KTK hopping for height	F = 5.563 *	F = 13.743 **	F = 11.407 **
KTK MQ	F = 6.567 *	F = 15.066 **	F = 2.248
basic skills	F = 27.803 **	F = 34.371 **	F = 31.9671 **
Discriminant Analysis			
cannonical correlation	Rcan = 0.452	Rcan = 0.486	Rcan = 0.419
Wilks Lambda	Wilks' Lambda = 0.796 and P < 0.001	Wilks' Lambda = 0.763 and P < 0.001	Wilks' Lambda = 0.824 and P < 0.001
df	17	17	17
correctly classified	68.7 %	79.4 %	87.7 %
negative	74.4 %	91.5 %	98.6 %
positive	61.8 %	47.8 %	22.9 %
false positive	25.6 %	8.5 %	1.4 %
false negative	38.2 %	52.2 %	77.1 %

The F-values indicated in this table are those for all variables in the overall discriminant function (* for $p < 0.05$ and ** for $p < 0.01$)

Finally, Survival Analysis was applied to predict the hazard ratio for each of the investigated talent characteristics using the cohorts 2008, 2009 and 2010 (n= 243). Kaplan – Meier Survival Analysis revealed that only 17.6% of the young gymnasts that performed the baseline test survived 5 years of high-level competition. The mean survival time of the three investigated cohorts was 2.5y (95%; 2.18 y to 2.76 y). Cox Regression revealed that basic motor skills and knee push-ups were significant ($p < 0.01$). Girls with a score < 68 for the motor basic skills increase their chance for dropout by 129% in relation to the girls with a score n > 82 (Figure 31).

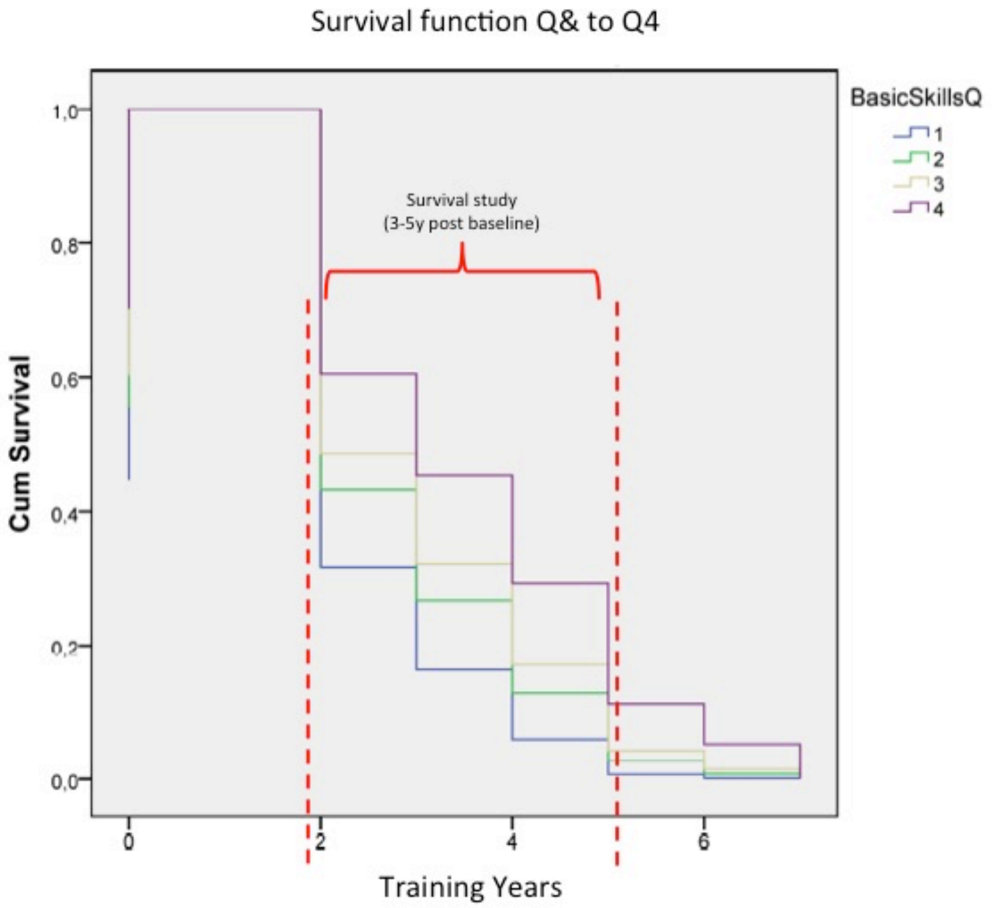


Figure 31 Survival plot with Basic Motor Skills as predictor

Note: the scores were divided into 4 groups (quartiles) Q1 score < 68, Q2 score = 68 to 75, Q3 score = 76 to 82 and Q4 score >82

The hazard ratio can be found in the Exp (B) column for Quartile 1 (basic skills =2.291) in

Table 19. This means that in relation to quartile 4 which always = 1.000, there is a 129.1 % higher hazard rate. Furthermore, girls performing less than 24 knee push-ups increased their chance for dropout by 91.3% compared to girls performing more than 31 knee push-ups.

An additional five measurements were also significant ($p < 0.05$). A 20-m sprint greater than 4.276 s increased the hazard ratio by 67.6% compared to sprint performed in less than 3.902 s; a counter movement jump <18.8 cm increased the chance to discontinue gymnastics by 53.4% compared to a score >23.8cm; For KTKBB a score lower than 57 increased the chance for dropping out by 63.0% compared to a perfect score of 72; the KTKHH increased hazard rate by 73.2% for girls scoring less than 56 points in comparison with gymnasts scoring more than 72 points and finally MQKTK <123 increased the chance to discontinue by 45% compared to a score >138.

Table 19: Quartile scores with Cox regression hazard ratios of anthropometry, physical and coordinative characteristics

	Total population	Quartile 1	Exp (B)	Quartile 2	Exp (B)	Quartile 3	Exp (B)	Quartile 4	Chi-square	df	Sig.
Anthropometry											
height (cm)	123.0 (6.1)	<118.9	0.991	118.9–122.2	1.021	122.3–127.3	0.941	>127.3	0.173	3	0.982
mass (kg)	22.7 (2.9)	<20.6	1.012	20.6–22.5	0.867	22.6–24.8	0.910	>24.8	1.252	3	0.741
BMI (kg/m^2)	14.96 (0.98)	<14.30	0.993	14.30–14.99	0.973	15.00–15.60	1.152	>15.60	1.293	3	0.731
fat % (%)	15.4 (3.0)	<13.5	1.077	13.5–15.4	0.912	15.5–17.3	1.272	>17.3	4.489	3	0.213
tanner index (cm)	63.3 (4.1)	>60.8	0.823	60.8–63.2	0.903	63.3–65.8	0.848	>65.8	1.652	3	0.648
Physical Characteristics											
sit and reach (cm)	32.0 (3.2)	<30	1.460	30–31	0.902	32–34	1.188	>34	8.153	3	0.043 *
sprint 20 m (s)	4.098 (0.267)	>4.276	1.676	4.082–4.276	1.397	3.902–4.081	1.136	<3.902	11.088	3	0.011 *
counter movement jump (cm)	21.5 (3.8)	<18.8	1.534	18.8–21.2	1.491	21.3–23.8	1.018	>23.8	11.147	3	0.011 *
knee push-ups (n/30 s)	28 (6)	<24	1.913	24–27	1.557	28–31	1.244	>31	13.904	3	0.003 **
sit-ups (n/30 s)	26 (8)	<21	1.272	21–25	0.959	26–31	1.256	>31	4.762	3	0.190
rope Skipping (n/60 s)	71 (25)	<54	1.375	54–70	1.176	71–88	1.017	>88	4.659	3	0.190
Motor Coordination											
KTK balance beam (n)	62 (9)	<57	1.630	57–63	1.271	64–71	1.154	>71	9;163	3	0.027 *
KTK jumping sideways (n/15 s)	66 (9)	<60	1.328	60–66	1.204	67–72	1.212	>72	3.109	3	0.375
KTK moving sideways (n/20 s)	43 (6)	<39	1.155	39–42	1.016	43–47	0.989	>47	1.127	3	0.771
KTK hopping for height (n)	62 (9)	<56	1.732	56–61	1.283	62–70	1.250	>70	10.655	3	0.014 *
KTK MQ (n)	130 (10)	<123	1.450	123–130	1.151	131–138	0.924	>138	8.039	3	0.045 *
basic skills (n)	75 (11)	<68	2.291	68–75	1.669	76–82	1.438	>82	26.170	3	<0.001 **

Discussion

This study investigated the link between performance characteristics assessed during talent identification and dropout in young female gymnasts. Kaplan-Meier analysis revealed that only 18% of the female gymnasts starting with the baseline test at the age of seven continued competition at A-level until the age of twelve. Six gymnasts continued at the highest competition level in Flanders (junior level A), with two qualifying for the European Team Finals in 2014. Gymnastics managers would consider two world-class gymnasts in each cohort as a successful outcome of a talent identification system. However, from the 91 participants that were tested in the first cohort, 93.4 % of the gymnasts (i.e. 85 gymnasts) do not attain the highest competition level. The displayed results from the Cox Proportional-Hazards Model explain that gymnasts with a score in the best quartile increase their chances to survive between 45% and 129% for basic motor skills (129%), knee push-ups (91%), KTKHH (73%), 20-m sprint (68%), KTKBB (63%), counter movement jump (53%) and the gross motor coordination measured by MQKTK (45%). Although, considering the basic motor skills test as a motor coordination assessment, it is clear that this test is closest related to the basic needs of gymnastics, which explains the higher hazard ratios. While, the low hazard ratios for anthropometric characteristics can possibly be explained to the natural selection that occurs early in the career.

According to Vaeyens and colleagues [24] excellence in sport is not idiosyncratic to a standard set of performance attributes. It can be achieved in individual or unique ways through different combinations. This effect has been termed the ‘compensation phenomenon’. When comparing Table

18 and Table 19 with the outcomes of the discriminant analysis and with the outcomes of the survival analysis

Table 19 it is clear that the survivors do not necessarily score in the best quartile (Q4) for each of the significant talent characteristics. Therefore, compensation may be possible between the different variables. For example the surviving gymnast with the lowest MQKTK (score = 123; Q4 >138) compensated this low score with superior scores for sit and reach (score = 34; Q4 >34); 20-m sprint (score = 3.717; Q4 <3.902); counter movement jump (score = 28.7; Q4 >23.8); knee push ups (score = 34; Q4 >31); KTKBB (score = 72; Q4 > 71); KTKHH (score = 78; Q4 > 72); and basic motor skills (score = 96; Q4 > 82).

Disengaging from gymnastics is a multi-dimensional process, with single factors unable to determine dropout [16]. Indeed, the decision to end a career might be the outcome of severe physical and mental exhaustion in older gymnasts (18y to 22y), resulting from heavy training at an early age [16]. According to previous research, athletic failure in gymnastics does not appear to be an important factor for the disengagement process [7] [16]. Contrastingly, the present study highlights that low scores for performance characteristics could be influential in the decision to withdraw from gymnastics competition. The discriminant analysis reveals that gymnasts do not last longer than 3 years in their sport when scoring low for flexibility, speed, strength, basic motor skills and gross motor coordination. In addition, the descriptive statistical analyses show that for every year that gymnasts continue their sport, the lowest score of the survivors increases. This suggests that the baseline results are more exigent for each year that gymnasts continue their sport. Therefore a gradual raise of the threshold scores of some characteristics might be designated to include the possibility of compensating for other talent characteristics. This outcome promotes the use of these tests for talent identification at a young age and for identifying specific training needs at all ages (supplemental material 3: examples of score sheets for TID).

Though the test battery used in this investigation was quite extensive, it may be limited by the absence of important psychological [1] and environmental factors [4,9]. In our opinion the lack of a psychological assessment is more important in a second phase, when gymnasts decide to start with a thorough training schedule. This generally occurs at the age of twelve, when the best gymnasts are selected for development at elite schools. Considering the high dropout rate before reaching this point it seems plausible to invest in a brief assessment of psychological and environmental characteristics at a younger age to prevent this early attrition.

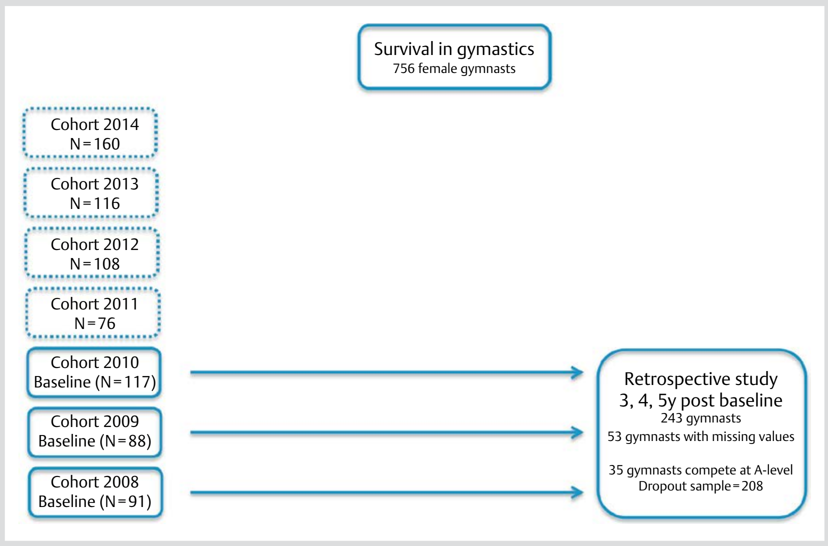
The high amount of withdrawals at the highest competition level observed in this investigation should encourage gymnastics managers to focus on the competencies of the children, guiding them to another gymnastic discipline in which they can excel. In this way, the test battery should not only focus on identifying for artistic gymnastics. Indeed, diversified involvement in a number of sports during early stages of development has been presented as a possible alternative to early specialization [3]. Therefore, a variety of different gymnastic disciplines not only provide opportunities for a complete gymnastic development but also for orientation towards complementary gymnastics disciplines. Rhythmic gymnastics could be an option for the most flexible gymnasts and trampoline and tumbling for the better jumpers.

The dropout rate in female artistic gymnastics is unusually high. Probably also the parents play an important role in the decision to invest these large amounts of training time, with possible impact on academic performance as well. Since elite gymnastics has only very limited financial reward, choices towards this high load sport are probably less evident and investment in academic success is preferred. Only one female gymnast out of five survives five years of competition in this demanding sport, requiring thirty hours of training per week. Performance characteristics appear important for identifying talent and potential dropout. Therefore, an identification test battery should not only provide selection criteria but also focus on possible transitions to other gymnastic disciplines or even other sports. Only the gymnasts with the very best profile on 'most' of performance-related parameters or best compensators are those that might have the highest chance of keeping up the high load as they get the better progress from their training efforts. The results should also encourage gymnastic trainers to invest in early development of basic physical and motor characteristics to prevent a complete attrition from sports participation.

(Table 20: Supplemental material 1: Descriptive statistics X (SD) of anthropometry, physical and coordinative characteristics and the minimum scores for each of the variables by years of survival in gymnastics.

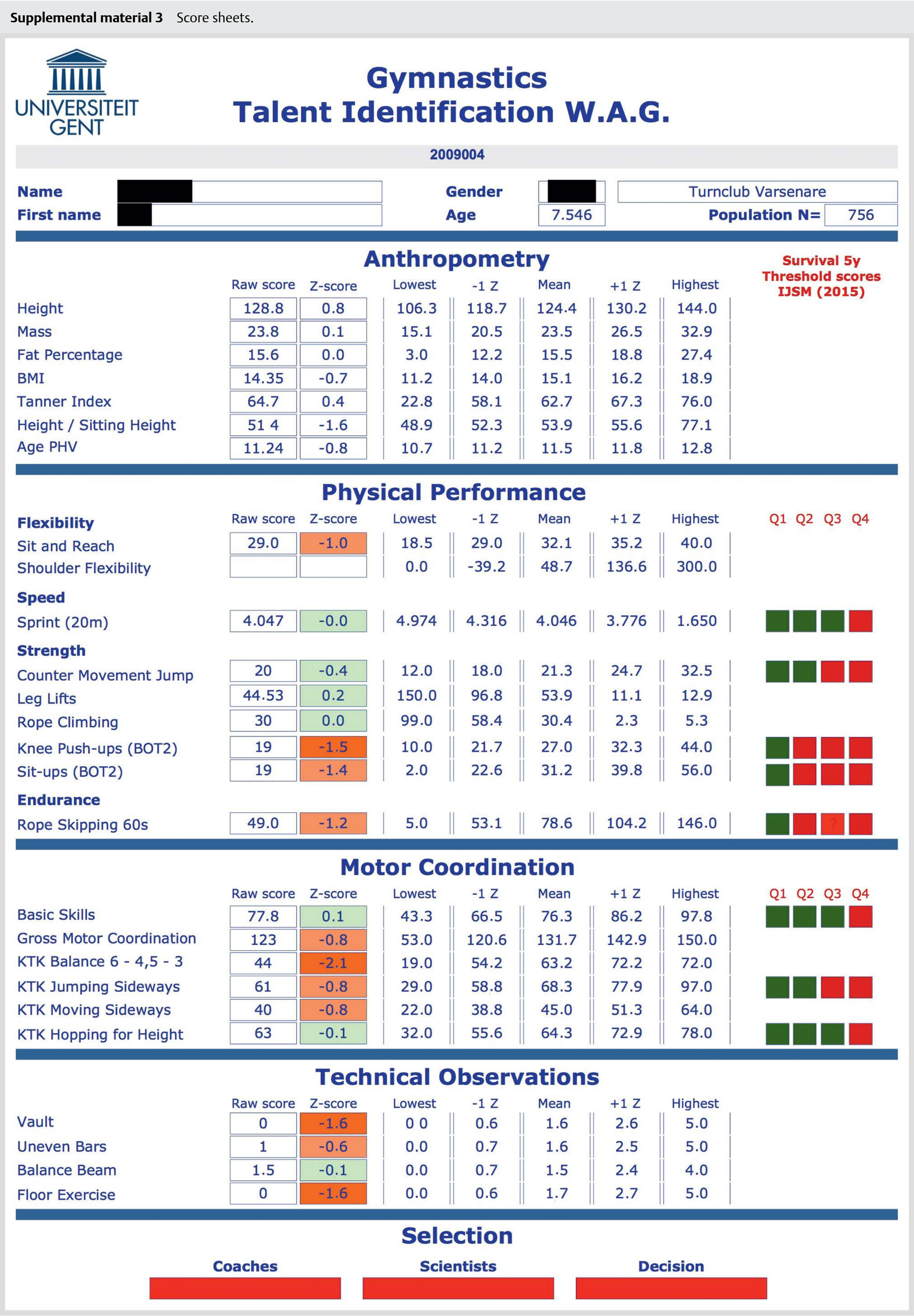
	Total population	**3y later**		**4y later**		**5y later**	
		survival	**Threshold**	**survival**	**Threshold**	**survival**	**Threshold**
	(n=243)	**(n=138)**	**value**	**(n=92)**	**value**	**(n=52)**	**value**
age (years)	7.7 (0.7)	7.7 (0.6)		7.7 (0.6)		7.8 (0.6)	
Anthropometry							
height (cm)	123.0 (6.1)	123.1 (5.9)	136.3	123.1 (6.0)	133.0	123.7 (5.8)	129.0
weight (kg)	22.7 (2.9)	22.8 (2.8)	31.8	22.8 (2.9)	27.5	22.9 (2.9)	26;1
BMI (kg/m^2)	14.96 (0.98)	15.01 (1.01)	17.12	14.98 (1.02)	16.41	14.89 (0.87)	16.41
fat % (%)	15.4 (3.0)	15.5 (3.3)	21.2	15.5 (3.2)	18.7	15.0 (2.8)	18.7
tanner index (cm)	63.3 (4.1)	63.3 (4.0)	75.9	63.1 (4.2)	66.9	63.1 (4.1)	66.9
Physical Characteristics							
sit and reach (cm)	32.0 (3.2)	32.7 (3.1)	25.5	32.8 (3.0)	29.0	32.7 (3.2)	31.0
sprint 20 m (s)	4.098 (0.267)	4.045 (0.233)	4.696	4.015 (0.232)	4.369	3.978 (0.243)	4.187
counter movement jump (cm)	21.5 (3.8)	21.8 (3.5)	15.4	22.3 (3.3)	19.4	23.2 (3.1)	22.4
knee push-ups (n/30 s)	28 (6)	29 (6)	12	30 (6)	18	31 (6)	30
sit-ups (n/30 s)	26 (8)	26 (8)	3	26 (8)	20	28 (9)	24
rope skipping (n/60 s)	71 (25)	75 (26)	32	77 (24)	41	81 (23)	60
Motor Coordination							
KTK balance beam (n)	62 (9)	64 (10)	32	65 (10)	32	65 (10)	62
KTK jumping sideways (n/15 s)	66 (9)	67 (10)	38	68 (10)	53	69 (10)	62
KTK moving sideways (n/20 s)	43 (6)	44 (6)	28	44 (6)	31	43 (7)	35
KTK hopping for height (n)	62 (9)	64 (9)	45	65 (8)	55	67 (8)	58
KTK MQ (n)	130 (10)	132 (9)	112	134 (9)	116	133 (9)	123
basic skills (n)	75 (11)	79 (10)	66	81 (9)	66	83 (8)	66

The threshold score is the lowest score in the cohort that reached the third, fourth and fifth year of competition. The gymnasts were tested at the baseline and the little change to mean and SD illustrates that the demands to survive 3, 4 or 5 years are higher



Supplemental material 2 Participants and cohorts.

Figure 32: Supplemental material 2: Participants and cohorts



Supplemental material 3 Score sheets.

UNIVERSITEIT GENT

Gymnastics
Talent Identification W.A.G.

2009004

Name	[redacted]	**Gender**	[redacted]
First name	[redacted]	**Age**	7.546
			Turnclub Varsenare
		Population N=	756

Anthropometry

Survival 5y Threshold scores IJSM (2015)

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest
Height	128.8	0.8	106.3	118.7	124.4	130.2	144.0
Mass	23.8	0.1	15.1	20.5	23.5	26.5	32.9
Fat Percentage	15.6	0.0	3.0	12.2	15.5	18.8	27.4
BMI	14.35	-0.7	11.2	14.0	15.1	16.2	18.9
Tanner Index	64.7	0.4	22.8	58.1	62.7	67.3	76.0
Height / Sitting Height	51 4	-1.6	48.9	52.3	53.9	55.6	77.1
Age PHV	11.24	-0.8	10.7	11.2	11.5	11.8	12.8

Physical Performance

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest	Q1	Q2	Q3	Q4
Flexibility											
Sit and Reach	29.0	-1.0	18.5	29.0	32.1	35.2	40.0				
Shoulder Flexibility			0.0	-39.2	48.7	136.6	300.0				
Speed											
Sprint (20m)	4.047	-0.0	4.974	4.316	4.046	3.776	1.650	🟩	🟩	🟩	🟥
Strength											
Counter Movement Jump	20	-0.4	12.0	18.0	21.3	24.7	32.5	🟩	🟩	🟥	🟥
Leg Lifts	44.53	0.2	150.0	96.8	53.9	11.1	12.9				
Rope Climbing	30	0.0	99.0	58.4	30.4	2.3	5.3				
Knee Push-ups (BOT2)	19	-1.5	10.0	21.7	27.0	32.3	44.0	🟩	🟥	🟥	🟥
Sit-ups (BOT2)	19	-1.4	2.0	22.6	31.2	39.8	56.0	🟩	🟥	🟥	🟥
Endurance											
Rope Skipping 60s	49.0	-1.2	5.0	53.1	78.6	104.2	146.0	🟩	🟥	?	🟥

Motor Coordination

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest	Q1	Q2	Q3	Q4
Basic Skills	77.8	0.1	43.3	66.5	76.3	86.2	97.8	🟩	🟩	🟩	🟥
Gross Motor Coordination	123	-0.8	53.0	120.6	131.7	142.9	150.0				
KTK Balance 6 - 4,5 - 3	44	-2.1	19.0	54.2	63.2	72.2	72.0				
KTK Jumping Sideways	61	-0.8	29.0	58.8	68.3	77.9	97.0	🟩	🟩	🟥	🟥
KTK Moving Sideways	40	-0.8	22.0	38.8	45.0	51.3	64.0				
KTK Hopping for Height	63	-0.1	32.0	55.6	64.3	72.9	78.0	🟩	🟩	🟩	🟥

Technical Observations

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest
Vault	0	-1.6	0 0	0.6	1.6	2.6	5.0
Uneven Bars	1	-0.6	0.0	0.7	1.6	2.5	5.0
Balance Beam	1.5	-0.1	0.0	0.7	1.5	2.4	4.0
Floor Exercise	0	-1.6	0.0	0.6	1.7	2.7	5.0

Selection

Coaches	Scientists	Decision
🟥	🟥	🟥

Figure 33: Suplemental material 3: score sheets.

Gymnastics
Talent Identification W.A.G.

2009017

Name	[redacted]	**Gender**	[redacted]	Corpus Sanum Herentals	
First name	[redacted]	**Age**	8.628	**Population N=**	756

Anthropometry

Survival 5y Threshold scores IJSM (2015)

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest
Height	126.4	0.3	106.3	118.7	124.4	130.2	144.0
Mass	22.3	-0.4	15.1	20.5	23.5	26.5	32.9
Fat Percentage	14.6	-0.3	3.0	12.2	15.5	18.8	27.4
BMI	13.96	-1.1	11.2	14.0	15.1	16.2	18.9
Tanner Index	65.6	0.6	22.8	58.1	62.7	67.3	76.0
Height / Sitting Height	53.6	-0.2	48.9	52.3	53.9	55.6	77.1
Age PHV	11.88	1.3	10.7	11.2	11.5	11.8	12.8

Physical Performance

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest	Q1	Q2	Q3	Q4
Flexibility											
Sit and Reach	35.0	0.9	18.5	29.0	32.1	35.2	40.0				
Shoulder Flexibility			0.0	-39.2	48.7	136.6	300.0				
Speed											
Sprint (20m)	3.841	0.8	4.974	4.316	4.046	3.776	1.650	🟩	🟩	🟩	🟩
Strength											
Counter Movement Jump	28	2.0	12.0	18.0	21.3	24.7	32.5	🟩	🟩	🟩	🟩
Leg Lifts	23	0.7	150.0	96.8	53.9	11.1	12.9				
Rope Climbing	8.03	0.8	99.0	58.4	30.4	2.3	5.3				
Knee Push-ups (BOT2)	32	0.9	10.0	21.7	27.0	32.3	44.0	🟩	🟩	🟩	🟩
Sit-ups (BOT2)	36	0.6	2.0	22.6	31.2	39.8	56.0	🟩	🟩	🟩	🟩
Endurance											
Rope Skipping 60s	118.0	1.5	5.0	53.1	78.6	104.2	146.0	🟩	🟩	🟩	🟩

Motor Coordination

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest	Q1	Q2	Q3	Q4
Basic Skills	88.9	1.3	43.3	66.5	76.3	86.2	97.8	🟩	🟩	🟩	🟩
Gross Motor Coordination	142	0.9	53.0	120.6	131.7	142.9	150.0				
KTK Balance 6 - 4,5 - 3	72	1.0	19.0	54.2	63.2	72.2	72.0				
KTK Jumping Sideways	80	1.2	29.0	58.8	68.3	77.9	97.0	🟩	🟩	🟩	🟩
KTK Moving Sideways	50	0.8	22.0	38.8	45.0	51.3	64.0				
KTK Hopping for Height	78	1.6	32.0	55.6	64.3	72.9	78.0	🟩	🟩	🟩	🟩

Technical Observations

	Raw score	Z-score	Lowest	-1 Z	Mean	+1 Z	Highest
Vault	2	0.4	0.0	0.6	1.6	2.6	5.0
Uneven Bars	2	0.4	0.0	0.7	1.6	2.5	5.0
Balance Beam	2	0.5	0.0	0.7	1.5	2.4	4.0
Floor Exercise	1	-0.6	0.0	0.6	1.7	2.7	5.0

Selection

Coaches	Scientists	Decision
🟩	🟩	🟩

References

1. Abbott A, Collins D. Eliminating the dichotomy between theory and practice in talent identification and development: considering the role of psychology. J Sport Sci 2004; 22: 395-408
2. Ahnert J, Schneider W, K B. Developmental changes and individual stability of motor abilities from the preschool period to young adulthood. In: Schneider W, Bullock MR eds, Human development from early childhood to early adulthood: Evidence from the Munich Longitudinal Study on the Genesis of individual Competencies (LOGIC). Mahwah: NJ: Erlbaum; 2009: 35-62
3. Baker J. Early specialization in youth sport: A requirement for adult expertise? High Abil Stud 2003; 14: 85 to 94
4. Baker J, Horton S. A review of primary and secondary influences on sport expertise. High Abil Stud 2004; 15: 211-228
5. Bruininks RH, Bruininks BD. BOT-2: Bruininks-Oseretsky Tests of Motor Proficiency. Second edition ed. Minneapolis: AGS Publishing; 2006
6. Butcher J, Lindner KJ, Johns DP. Withdrawal from competitive youth sport: A retrospective ten-year study. Journal of Sport Behavior 2002; 25: 145-163
7. Claessens AL, Lefevre J. Morphological and performance characteristics as dropout indicators in female gymnasts. J Sport Med Phys Fit 1998; 38: 305-309
8. Claessens AL, Lefevre J, Beunen G, Malina RM. The contribution of anthropometric characteristics to performance scores in elite female gymnasts. J Sport Med Phys Fit 1999; 39: 355-360
9. Coté J. The influence of the family in the development of talent in sport. Sport Psychol 1999; 13: 395-417
10. Council of Europe. Eurofit: Handbook for the EUROFIT Tests of Physical Fitness. Rome: Secretariat of the Committee for the Development of Sport within the Council of Europe; 1988
11. Ericsson KA, Krampe RT, Teschromer C. The Role of Deliberate Practice in the Acquisition of Expert Performance. Psychol Rev 1993; 100: 363-406
12. Fraser-Thomas J, Coté J, Deakin J. Examining adolescent sport dropout and prolonged engagement from a developmental perspective. J Appl Sport Psychol 2008; 20: 318-333
13. Gould D, Udry E, Tuffey S, Loehr J. Reasons for attrition in competitive youth swimming. Journal of Sport Behavior 1982; 5: 155-165
14. Harriss DJ, Atkinson G. International Journal of Sports Medicine - Ethical Standards in Sport and Exercise Science Research: 2014 update. Int J Sports Med 2013; 34(12): 1025-1028. DOI: 10.1055/s-0033-1358756
15. Kiphard EJ, Schilling F. Körperkoordinationstest für Kinder. 2. Überarbeitete und ergänzte Auflage. ed. Weinheim: Beltz: Test GmbH.; 2007
16. Koukouris K. Premature athletic disengagement of elite Greek gymnasts. European Journal for Sport and Society 2005; 2: 35-56
17. Lidor R, Hershko Y, Bilkevitz A, Arnon M, Falk B. Measurement of talent in volleyball: 15-month follow-up of elite adolescent players. J Sport Med Phys Fit 2007; 47: 159-168
18. Lohman TM, Roche AF, Martorell R. Anthropometric standardization reference manual. Champaign IL: Human Kinetics; 1988
19. Lopes VP, Rodrigues LP, Maia JAR, Malina RM. Motor coordination as predictor of physical activity in childhood. Scand J Med Sci Spor 2011; 21: 663-669
20. Petlichkoff LM. Psychology of Sport - the Behavior, Motivation, Personality, and Performance of Athletes, 2nd Edition - Butt,Ds. J Sport Exercise Psy 1989; 11: 346-348
21. Prescott J. Identification and development of talent in young female gymnasts. Loughborough University; 1999:
22. Russell J, Martindale J, Collins D, Abraham A. Effective Talent Development: The Elite Coach Perspective in UK Sport. J Appl Sport Psychol 2010; 19: 187-206
23. Tabachnick BG, Fidell LS. Using Multivariate Statistics. 5 ed. Boston: Pearson Education Inc.; 2007
24. Vaeyens R, Lenoir M, Williams AM, Philippaerts RM. Talent identification and development programmes in sport - Current models and future directions. Sports Med 2008; 38: 703-714
25. Vandorpe B, Vandendriessche J, Vaeyens R, Pion J, Lefevre J, Philippaerts R, Lenoir M. Factors Discriminating Gymnasts by Competitive Level. Int J Sports Med 2011; 32: 591-597
26. Vandorpe B, Vandendriessche JB, Vaeyens R, Pion J, Lefevre J, Philippaerts RM, Lenoir M. The value of a non-sport-specific motor test battery in predicting performance in young female gymnasts. J Sport Sci 2012; 30: 497-505

27. Weiss MR, Williams L. The why of youth sport involvement: A developmental perspective on motivational processes. In: Weiss MR ed, Developmental Sport and Exercise Psychology: A Lifespan Perspective. Morgantown: WV:Fitness Information Technology; 2004: 223-268

When people start asking you to do the same thing over ond over again.

That’s when you know you’re way too close to something that you don’t want to be near.

(Neil Young)

2.3.3 PAPER 6: PREDICTIVE MODELS REDUCE TALENT DEVELOPMENT COSTS IN FEMALE GYMNASTICS

Journal of Science and Medicine in Sport

Pion, J.*, Hohmann, A.*, Tianbiao Liu[2, 3], Vandorpe, B., Lenoir, M.,Segers, V.

Pion, J. and Hohmann, A. share first authorship for this article

Submitted March 23 2015

Abstract

Objectives

Talent identification programs are installed to select high potential female gymnasts. Still, the prediction of future performance is difficult and featured by a significant dropout, which entails superfluous expenses.

Design

This retrospective study focuses on the comparison of different predictive models based on the results of a talent identification test battery. We studied to what extent these models have the potential to optimize selection procedures, and at the same time reduce talent development costs in female artistic gymnastics.

Methods

The dropout rate of 243 female elite gymnasts was investigated, 5 years past talent selection. The coaches' decisions were compared to linear (Discriminant Analysis) and non-linear predictive models (Kohonen Feature Maps and Multi layer Perceptron).

Results

The coaches classified 51.9% of the participants correct. Discriminant analysis improved the correct classification to 71.6% while the non-linear technique of Kohonen Feature Maps reached 73.7% correctness. Application of the Multi Layer Perceptron even classified 79.8% of the gymnasts correctly.

Conclusions

The combination of different predictive models for talent selection can avoid de-selection of high potential female gymnasts. However, a 100% correct prediction is yet not possible due to the multi-dimensional elite characteristics that are not all included in the test battery. The selection procedure based upon the different statistical analyses results in decrease of 33.3% of cost because the pool of selected athletes can be reduced to 92 instead of 138 gymnasts (as selected by the coaches). Reduction of the costs allows the limited resources to be fully invested in the high-potential athletes.

Introduction

In many countries talent identification programs are installed in an attempt to spend available resources more effectively. Indeed, the increasing competition between nations for medals at major international competitions and the downward trend in the economy has driven many national sporting organisations to select high potential athletes well in advance of their age of maximal performance [1]. Predicting future performance is difficult, especially in early specialisation sports in which athletes make their appearance at the highest competition level at a relatively young age. The search for elite characteristics in early phases of talent development can be used to predict future performance of the individual athlete, as well as the athletes' chances to reach the highest level of proficiency in their specific sport [2]. Sports organisations might benefit from scientific test batteries to identify and select individuals with the highest potential in an objective manner, which take risks and costs into account. Unfortunately, the actual selection is often based on subjective coaches' impressions of the results.

Women's competitive gymnastics is a multifaceted sport that requires a high level of physical fitness and skill to succeed. Speed, strength, endurance, agility, flexibility, balance, and power are all physical abilities that play a role in the success of a competitive gymnast [3] Cross-sectional studies in gymnastics highlighted the importance of anthropometric, physical and motor characteristics for performance in gymnastics by distinguishing gymnasts from other athletic populations or controls [4-6]. These comparisons result in valuable information on the characteristics that increase the chances of a young gymnast to succeed. Predictability of future success is an important criterion for effective Talent Identification (TID) test batteries [7]. In one of the few longitudinal studies Prescott [8] determined which characteristics were able to predict future performance. Extracting knowledge from large amounts of data collected in young female gymnasts 6 to 9 years old by Vandorpe and colleagues [9] during five consecutive years provides a gateway for the use of non-linear analyses. However, in most studies in the context of talent identification linear statistical methods have been applied. The efforts made to identify and select the better female gymnasts without losing the high potentials are high and yet there is a lot of dropout [10].

The interrelations between different talent characteristics show different patterns due to compensation (29). For example, extremely high scores for balance and flexibility might compensate mediocre scores for speed or strength in gymnasts. Indeed the different variables lead to non-linear character of the data. Therefore, artificial neural networks (ANNs) have shown to provide new opportunities. An ANN is a massively parallel-distributed processor that has a natural propensity for storing experiential knowledge and making it available for use [11]. It resembles the brain in two respects: first knowledge is acquired by the network through a learning process and second interneuron connection strengths known as synaptic weights are used to store the knowledge. An ANN can approximate a wide range of statistical models without the need of hypotheses made in advance of certain relationships between the dependent and independent variables. If a linear relationship between the dependent and independent variables is appropriate, the results of the ANN should closely approximate those of a discriminant analysis (DA). The Discriminant Analysis is not a neural network technique, but also a tool for (statistical) classification and is widely used for the purpose of talent prognosis. In fact, a DA has a rigid model structure and set of assumptions that are imposed before learning from the data. By contrast, the neural network makes minimal demands on model structure and assumptions. Instead, the form of the relationships is determined during the learning process. If a non-linear relationship is more appropriate, the ANN will automatically approximate the “correct” model structure [12].

The potential of ANN techniques in sports sciences can be demonstrated in different domains of applications. A first type of application of ANNs in sports is the evaluation of game strategies for example in soccer [13]. A second type of applications was used for the prediction of competition performances in football and swimming [14]. Furthermore non-linear methods were also used for analysis in talent identification. Maszczyk et al. [15] predicted results in javelin throwing by multi layer perceptron (MLP). Rygula and Roczniok [16] used MLP, while Pfeiffer and Hohmann [17] used Self Organising Kohonen Feature Maps (KFM) to predict swimming performance. More recently, Allen et al. [1] compared the predictive accuracy of four methods for early selection of Australia’s 2012 Olympic-qualifying swimmers using a retrospective simulation approach.

The present retrospective study focuses on the performance characteristics assessed five years prior to status of competition participation at the highest level in Flanders (A-level). The pending question is whether predictive models can reduce the talent development costs in female gymnastics. We investigate to what extent survival in female gymnastics can be predicted using linear mathematic methods by means of discriminant analysis and/or non-linear mathematic methods through artificial neural networks by means of Kohonen Feature Maps and Multi Layer Perceptron. The results of the predictive models will be compared with the results of the prior decisions made by the coaches at baseline. The authors hypothesize that talent identification based upon artificial networks is more accurate than linear predictive models and the decision of the coaches. This hypothesis implies that implementing a more scientific approach could reduce the talent development costs in female gymnastics.

Methods

Every year clubs are invited to participate at the baseline test organized by GymFed in Flanders (282 clubs and 107.880 members). Trainers of 81 competitive gymnastic clubs made a pre-selection and their best young female gymnasts from a high national level (7.7 ± 0.7 y) performed the gymnastic talent identification test battery developed by Vandorpe et al. [18]. This resulted in seven cohorts (2008 to 2014) with 756 participants. In the scope of this study the three first cohorts containing 243 gymnasts were included in the study sample to compare the accuracy and the profit of the predictive models with the precision and profit of the prior decisions made by the coaches at baseline. The project has been conducted in accordance with recognised ethical standards (reference) and was approved by the local Ethics Committee of the Ghent University Hospital. For all participants written informed parental consent was obtained.

The multidimensional talent identification assessment developed by Vandorpe and colleagues [9], consisted of five anthropometric, five physical performance and three motor coordination tests. Only eight tests showed significant differences (T-test, $p < .01$) between dropout and survivors and were therefore included in his study i.e. 20m sprint, counter movement jump, knee push-ups, sit-ups, rope skipping, KTK jumping sideways, KTK hopping for height, basic motor skills.

A sequential discriminant analysis (DA), and two artificial neural network methods i.e. Kohonen Feature Maps (KFM) and Multi Layer perceptron (MLP) were applied to define the gymnasts continuing and discontinuing competition. The validation of the three predictive models was conducted using the leave-one-out method of cross-validation. Cross-validation analysis takes subsets of data for training and testing and is needed in order to understand the usefulness of the predictive model when classifying new data. This method involves generating the discriminant function or to train the artificial neural networks on all but one of the participants (n-1) and then testing for group membership on that participant. The process is repeated for each participant (n times) and the percentage of correct classifications generated through averaging for the n trials. The DA (significance for was set at $p<0.05$) and MLP were performed using IBM SPSS v 22 and the KFM was performed using (Data engine v4.0, MIT, Aachen).

First, DA was applied to investigate relevant performance measures in female gymnastics. In this analysis, belonging to either the gymnasts continuing (survivors) or the gymnasts discontinuing their sport (dropouts) was the grouping variable and the independent variables were the eight performance characteristics.

Second KFM were applied using the survivor sample (n=35) 4 times to resize the group (n=140) and the dropouts (n=208) as grouping variables and 8 bivariate validated independent variables ($p< .05$). The self-organizing map was configured as a 5x5 KFM and training for every subject was set at 1.000 iterations. Five predictions were registered for all participating gymnasts. All subjects that were at least once identified as a survivor the gymnast were assigned to the group of survivors.

A third predicitive model was build, using artificial neural networks by means of Multi Layer Perceptron (MLP). The input layer contained the eight different talent characteristics and the output layer contained two neurons to calculate the gymnasts in competition and the gymnasts that dropped out five years past baseline test. If a subject was at least once identified as a survivor the gymnast was assigned to the group of survivors.

Results

From the initial 243 gymnasts, only 35 gymnasts (14.4%) remain in competition at the highest level, while 208 young potentials discontinued gymnastics after five years. At baseline 138 female gymnasts (28 correctly classified survivors) were selected, implying that the coaches deselected 105 gymnasts**.** The baseline selection of the GymFed resulted in 51.90% correct classifications **(**Table 21**)** **(**Figure 34**).** At baseline 28 gymnasts 'surviving at the highest competition level' were selected and 7 gymnasts were deselected (false negatives). In the dropout group, 98 gymnasts were deselected and 110 gymnasts were selected (false positives).

Table 21: Classification results from the different models.

	Selection Gymfed	**Discriminant analysis**	**Kohonen Feature Maps**	**Multi Layer Perceptron**
Correctly classified	**51,90%**	**76,50%**	**73,70%**	**80,20%**
Correctly classified survivors	**80,0%** (28/35)	**60,0%** (21/35)	**51,4%** (18/35)	**40,0%** (14/35)
False negatives	**20%** (7/35)	**40,0%** (14/35)	**48,6%** (17/35)	**60,0%** (21/35)
Correctly classified dropouts	**47,1%** (98/208)	**79,3%** (165/208)	**77,4%** (161/208)	**87,0%** (181/208)
False positives	**52,9%** (110/208)	**20,7%** (43/208)	**22,6%** (47/208)	**13,0%** (27/208)

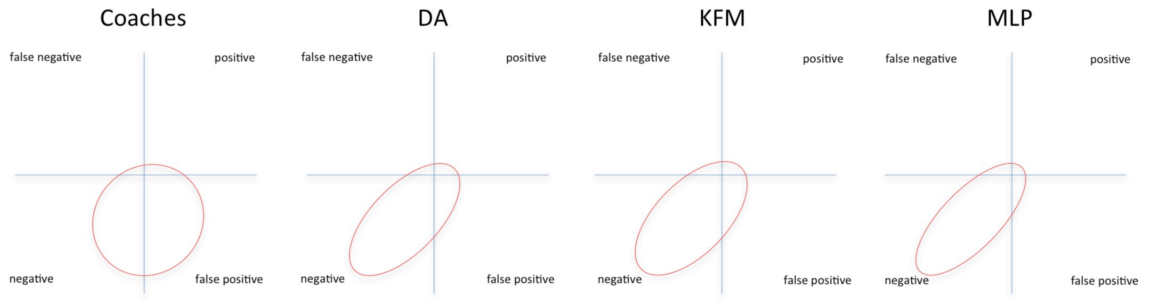


Figure 34: Different outcomes of talent identification models.

Note: The graphs are divided into 4 quadrants. The quadrants on the right represent the selected gymnasts and the quadrants above the horizontal axis represent the survivors (5 y past baseline test)

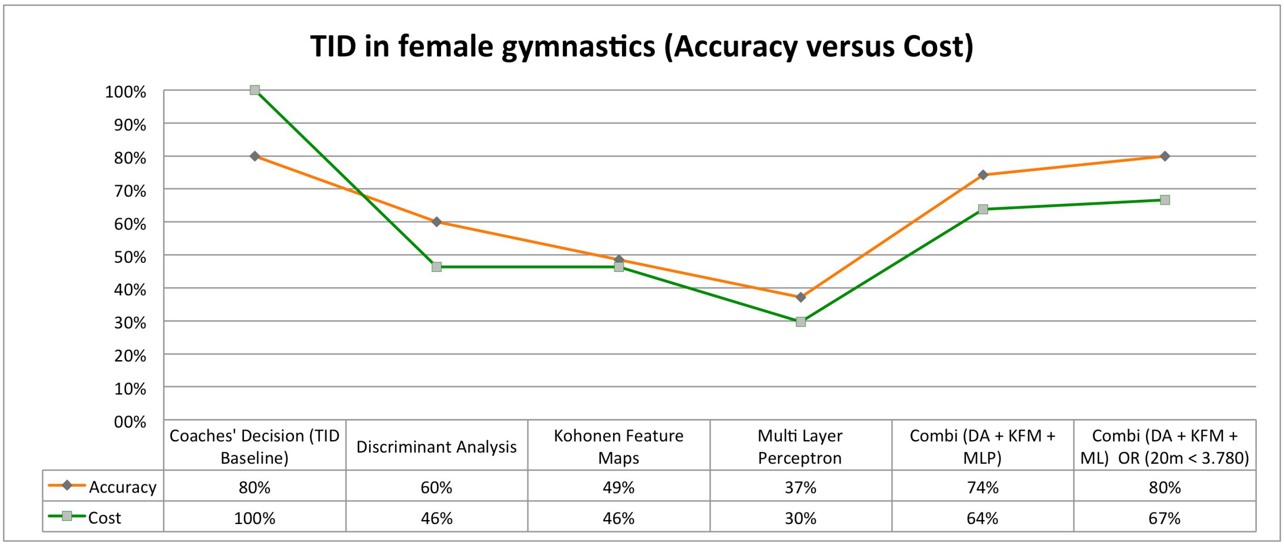
First, a linear predictive model by means of a Discriminant Analysis (DA) was applied. The DA classified 71.6% of the gymnasts in the correct group when using the result of the selection as grouping variable (df = 8; rcan = 0.513; Wilks' Λ = 0.737 and P <0.001). Twenty-one survivors were classified correctly and fourteen survivors were classified false negative, while 165 dropouts were classified correctly and 43 were classified false positive. Subsequently, two non-linear predictive Artificial Neural Networks (A.N.N.) i.e. Kohonen Feature Maps, (KFM) and Multi Layer Perceptron (MLP) were applied to increase the discrimination rate between survivors and dropouts. The KFM classified 73.7% of all participants correctly. Eighteen survivors were classified correctly and seventeen survivors were classified false negative, while 161 dropouts were classified correctly and 47 were classified false positive. The MLP classified 79.8% of all participants correctly. Thirteen survivors were classified correctly and twenty-two survivors were classified false negative, while 181 dropouts were classified correctly and 27 were classified false positive. Finally, it was possible to predict 26 gymnasts as future survivors when combining the results of the DA (correctly classified survivors = 21) with the results of the KFM (correctly classified survivors = 18) and the MLP (correctly classified survivors = 13). The combination of the predictive models results into 88 selected gymnasts.

Discussion

In this retrospective study the cost for talent development in female gymnastics was taken into consideration. Erroneous selections have not only a financial impact, other inconveniences are equally important when taking into account the commitment of trainers, clubs and sports federations and the disappointment of the discontinuing gymnast. Decreasing the costs is possible if fewer gymnasts are selected at the baseline, although this entails the risk of losing high potentials. Two perspectives were approached in order to optimize the selection procedure and the related costs for talent development. First the cost reduction was expressed as the number of selected gymnasts and second the accuracy of the selection was expressed as the correctly classified gymnasts in the survivor group. At the baseline 138 from 243 female gymnasts were selected after an evaluation of the test results and the coaches' decisions. The selection consisted of 28 correctly classified survivors and 110 false positives. Only 51.9% participants were classified correctly when comparing to the gymnasts that were still in competition 5 years later. Lidor and colleagues [19] already warned for the limitations associated with the use of TID test batteries that may decrease the probability of accurately predicting future success. Indeed unilateral testing in stationary settings and performed in a rested state differ from competitive situations, which does not necessarily mean that the hidden information in the data can be interpreted differently.

The various predictive models that were used in this study resulted in cost reduction although the risk of not identifying a gymnast was higher than the selection at baseline. First, the cross-validated discriminant analysis resulted in 71.6% correctly classified gymnasts and resulted in a 54% smaller selection (n= 64) than the selection at baseline (n=138). However, only 21 gymnasts that maintained the highest gymnastic level for at least five years were identified. Second, the predictive models using artificial neural networks by means of Kohonen Feature Maps (KFM) and Multi Layer Perceptron (MLP) showed even better results for the cost reduction. Unfortunately the risk to neglect high potentials was higher. The KFM classified 73.7% gymnasts correctly and resulted in a selection of 64 female gymnasts with the same gain (54%) as the discriminant analysis and a higher risk, since this method identified four gymnasts less than the coaches' decisions. The MLP classified 80.2% of the gymnasts correctly and reduced the costs with 70.3%. Only 41 gymnasts were selected with a higher risk to de-select the better gymnasts. The MLP identified only 13 of the 35 competitive gymnasts 5 years post baseline. Subsequently, an attempt was made to reduce the costs and to minimize the risk by combining the different predictive models.

The combination of the results from the talent identification system and the predictive methods resulted in the identification of 26 high potentials. The combination of the predictive methods reaches almost the accuracy of the coaches' decision at the baseline with a 36.2% reduction of the costs since the selection contains 88 gymnasts instead 138. The de-selection of gymnasts that still compete at the highest level is an incorrect estimation to be avoided in the future. The combined predictive methods identified fifteen gymnasts that were not identified by the coaches. The argument that four gymnasts are still in competition proves that the analyses add value to the current TID-system. Pion and colleagues and Lidor and colleagues [20-22] have repeatedly showed the importance of TID test batteries. The present study however demonstrates that selections based upon test results are more accurate and cost saving when using DA, KFM and MLP methods instead of a motivated first impression of the results by coaches and scientists. To equalize the risk an exceptional test score for sprint 20m (<3.780), was added to the combined predictive methods and this resulted in 28 identified gymnasts in a selection of 92 (Figure 35**).** Implementing a threshold score for speed after applying the combined predictive models results in a minimal risk of including extra gymnasts but allows identifying gymnasts who compensate their 'rather mediocre' scores with 'outstanding' scores for speed. The cost reduction for this option was 33.3%.



	Coaches' Decision (TID Baseline)	Discriminant Analysis	Kohonen Feature Maps	Multi Layer Perceptron	Combi (DA + KFM + MLP)	Combi (DA + KFM + ML) OR (20m < 3.780)
◆ Accuracy	80%	60%	49%	37%	74%	80%
■ Cost	100%	46%	46%	30%	64%	67%

Figure 35: Balance between accuracy and cost in talent identification (female gymnastics)

Note: The coaches' decision at baseline is a 100% cost for the actual talent identification program (measured by the amount of selected athletes at baseline). Different techniques can influence the decision for selection of the high potentials. To reach the same accuracy as the coaches' decision i.e. 80%, a combination of statistical techniques will finally result in a cost reduction of 33,3%.

The use of predictive models improves the talent identification system although it is still difficult at this stage to make a 100% correct prediction. The updated talent identification system is not able to classify all gymnasts correctly. The identification of the pending 7 gymnasts is difficult since no exceptional scores were registered for the performance tests. Motivation, persistence, training and maturity may also influence the outcome. However, when taking into account the maturity offset calculated according to Mirwald and colleagues [23] it was shown that the 7 gymnasts all had a maturity offset less than < 3.960y. Including these gymnast to the selection based on the maturity offset implies that another 69 gymnasts correctly classified as dropout meet the same maturity offset conditions. The target of 100% riskless TID-system has the consequence that the selection pool will consist of 161 gymnasts and the expenses will raise with 16.7% of the actual costs. The balance between risk and cost is a discussion for sporting organisations in their quest for medals.

Conclusions

The use of a specific test battery is only the first step towards a cost and risk reducing talent identification. Artificial neural networks and discriminant analysis are to be considered as a cost-effective approach in the resolution of complex problems such as the talent identification and dropout in gymnastics. Meanwhile it is important to reduce the risk of missing high potentials and it appears that performance characteristics are important for identifying talent and potential dropout. Most dropout studies [24-27] related to sports focus on motivation and socio-economic issues. If young gymnasts have to choose between large amounts of training time with a high training load or an investment in study time, they experience the pressure of their parents and peers to decide whether to continue or not with their sport. The implementation of questionnaires at baseline might not be a major problem to obtain data on confidence, optimism, mental toughness and coachability and to reduce the risk of missing gymnasts [28, 29]. So far the coaches' decisions were necessary for talent identification in gymnastics. Ignoring their competence will reduce the cost but has the disadvantage that the coaches have to work with gymnasts in which they have less faith.

As a conclusion this study indicates that best pathway for talent identification is the combination of the predictive models with an exceptional speed i.e. 20m in less than 3.780 s. This optimal cost-risk balance leads to an accurate prediction of future success and a 33.3% lower cost for talent development in female gymnastics.

Practical Implications

- Dropout is a significant problem in an early specialisation sport like female artistic gymnastics, resulting in personal disappointments and investments in resources that do not result in the success aimed at.
- The assessment of the right tests, i.e. tests allowing identification of potential rather than performance, is a first step towards a correct selection of young talents.
- Specialised coaches play a prominent role in the identification of young athletes that are supposed to possess the potential to excel. The results of this study indicate that the use of predictive models can further reduce the risk of missing high potential gymnasts in the talent identification process.
- The use of predictive models based upon non-linear statistics reduces the number of identified female gymnasts, resulting in more resources for a better talent development program for fewer athletes.

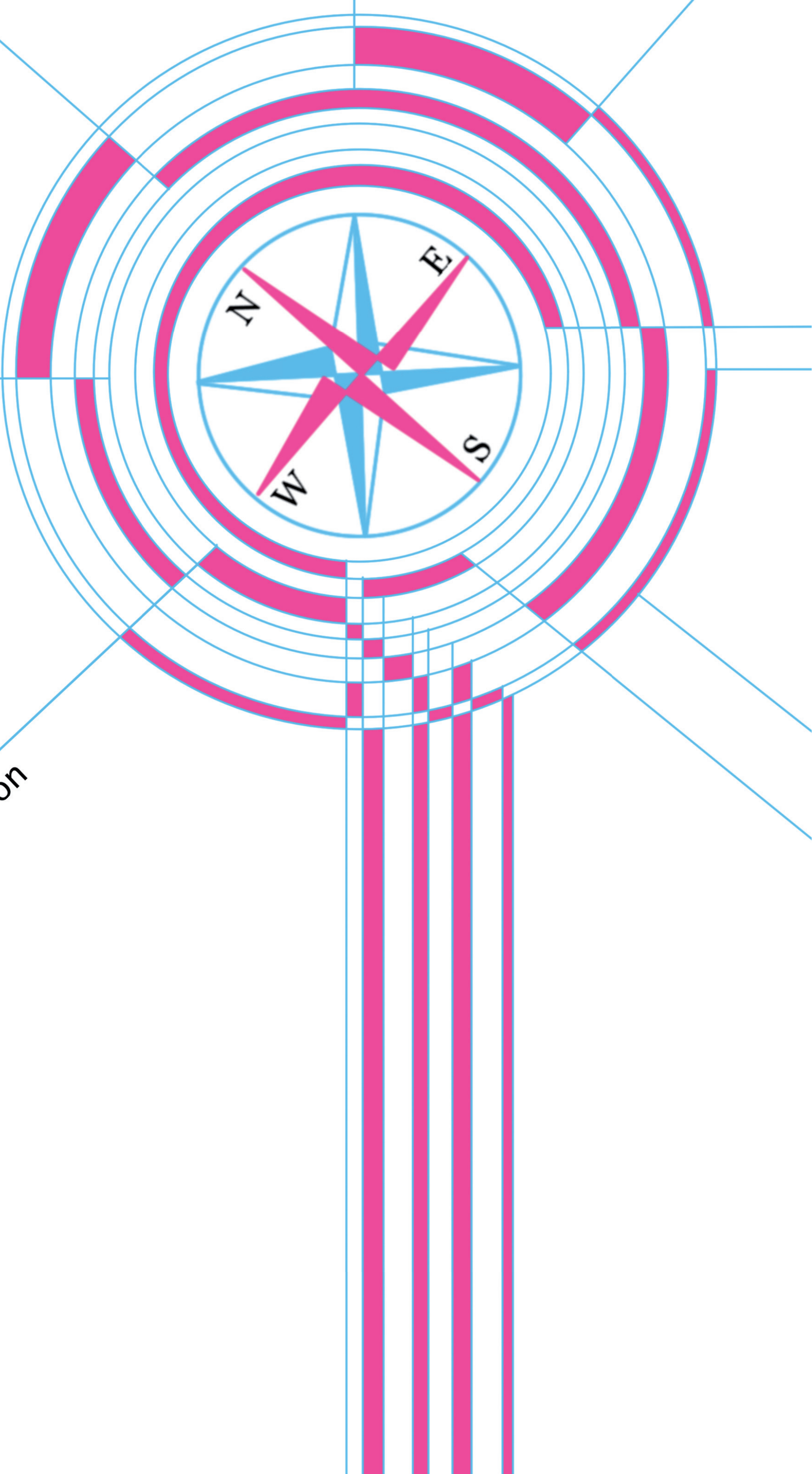
Acknowledgements

The Flemish Government, Department of Culture, Youth, Sports and Media funded this study.

References

1. Allen SV, Vandenbogaerde TJ, Pyne DB, et al. Predicting a Nation's Olympic-Qualifying Swimmers. Int J Sports Physiol Perform. 2014.
2. Ziv G, Lidor R. Anthropometrics, Physical Characteristics, Physiological Attributes, and Sport-Specific Skills in Under-14 Athletes Involved in Early Phases of Talent Development-A review. J Athl Enhancement. 2014; 3:6.
3. Sleeper MD, Kenyon LK, Casey E. Measuring fitness in female gymnasts: the gymnastics functional measurement tool. Int J Sports Phys Ther. 2012; 7(2): 124-138.
4. Maffulli N, King JB, Helms P; Training in elite young athletes (the Training of Young Athletes (TOYA) Study): injuries, flexibility and isometric strength. Br J Sports Med. 1994; 28(2):123-136.
5. Bencke J, Damsgaard R, Saekmose A, et al. Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming. Scand J Med Sci Sports. 2002; 12(3):171-178.
6. Pion J, Segers V, Fransen J, et al. Generic anthropometric and performance characteristics among elite adolescent boys in nine different sports. Eur J Sport Sci. 2014:1-10.
7. Régnier G, Salmela JH, Russell JC. Talent detection and development in sport, in Handbook of research in sport psychology. Singer RN, Murphy M, Tennant LK, eds. New York, Wiley, 1993.
8. Prescott J. Identification and development of talent in young female gymnasts. Loughborough University; 1999.
9. Vandorpe B, Vandendriessche J, Vaeyens R, et al. Factors Discriminating Gymnasts by Competitive Level. Int J Sports Med. 2011; 32(8):591-597.
10. Pion J, Lenoir M, Vandorpe B, et al. Talent in female gymnastics: a survival analysis based upon performance characteristics Int J Sports Med 2015 (36): 1-6 DOI http://dx.doi.org/10.1055/s-0035-1548887.
11. Haykin S. Neural Networks: A Comprehensive Foundation, 2nd ed., New York, Macmillan College Publishing; 1998.
12. IBM. IBM SPSS Neural Networks 20. Chicago USA: IBM Corporation; 2011.
13. Liu T. Systematische Spielbeobachtung im internationalen Leistungsfussball. Kulturwissenschaftlichen Fakultät. Vol Phd. Bayreuth: Universität Bayreuth; 2014:62.
14. Pyne DB, Gardner AS, Sheehan K, et al. Fitness testing and career progression in AFL football. J Sci Med Sport. 2005; 8(3):321-332.
15. Maszczyk A, Golas A, Pietraszewski P, et al. Application of Neural and regression Models in Sport Results Predicition. Soc & Behav Sci. 2014; 117:482-487.
16. Rygula I, Roczniok R. Application of Neural Networks in optimization of the recruitment proces for sport swimming. J Med Inform & Tech. 2004; 7.
17. Pfeiffer M, Hohmann A. Applications of neural networks in training science. Hum Movement Sci. 2012; 31(2):344-359.
18. Vandorpe B, Vandendriessche JB, Vaeyens R, et al. The value of a non-sport-specific motor test battery in predicting performance in young female gymnasts. J Sport Sci. 2012; 30(5):497-505.
19. Lidor R, Côté J, Hackfort D. ISSP Position Stand: To test or not to test? The use of physical skill tests in talent detectIon and in early phases of sport development. Int J of Sport and Ex Psych.2009; 9:131-146.
20. Mohamed H, Vaeyens R, Matthys S, et al. Anthropometric and performance measures for the development of a talent detection and identification model in youth handball. J Sport Sci. 2009; 27(3):257-266.
21. Vaeyens R, Lenoir M, Williams AM, et al. Talent identification and development programmes in sport - Current models and future directions. Sports Med. 2008; 38(9):703-714.
22. Lidor R, Hershko Y, Bilkevitz A, et al. Measurement of talent in volleyball: 15-month follow-up of elite adolescent players. J Sport Med Phys Fit. 2007; 47(2):159-168.
23. Mirwald RL, Baxter-Jones ADG, Bailey DA, et al. An assessment of maturity from anthropometric measurements. Med Sci Sport Exer.2002; 34(4):689-694.
24. Gould D, Udry E, Tuffey S, et al. Reasons for attrition in competitive youth swimming. J Sport Behavior. 1982; 5:155.
25. Fraser-Thomas J, Coté J, Deakin J. Understanding dropout and prolonged engagement in adolescent competitive sport. Psychol Sport Exerc. 2008; 9(5):645-662.

26. Petlichkoff LM. Psychology of Sport - the Behavior, Motivation, Personality, and Performance of Athletes, 2nd Edition - Butt,Ds. J Sport Exercise Psy. 1989; 11(3):346-348.
27. Koukouris K. Premature athletic disengagement of elite Greek gymnasts. Eur J Sport & Society. 2005; 2:35-56.
28. Gould D, Diefenbach K, Moffett A. Psychological characteristics and their development in Olympic champions. J Appl Sport Psychol. 2002; 14:172-204.
29. Weissensteiner J, Abernethy B, Farrow D, et al. Distinguishing psychological characteristics of expert cricket batsmen. J Sci Med Sport. 2012; 15:74-79.



Part 3: Discussion

3.1 GENERAL DISCUSSION, REFLECTIONS AND RECOMMENDATIONS

3.1.1 PRINCIPAL FINDINGS

The studies described in this dissertation aimed at gaining insight in the search of sports talent. A generic test battery was applied to determine how to optimize the processes in the spectrum from the detection of the ‘better movers’ to the survival chances of the elite athletes in their development for sports successes. This final chapter summarizes the main findings of our studies and provides several recommendations based on critical and scientifically based reflections. The different studies in this dissertation demonstrated the costs for talent identification could be reduced. However one should always be very cautious not losing gifted children (Pion, Hohmann, Liu, et al, 2015). We demonstrated that it is possible to predict survival chances in elite sport based on the results of a talent identification test battery using both the traditional (linear) statistics as well as the more advanced non-linear statistical techniques (neural networks) (gymnastics: Pion, Lenoir, Vandorpe, et al, 2015). Our studies investigating the chances to succeed are based on a generic approach for talent detection (Pion, Fransen, Deprez et al, 2014; Pion, Segers, Fransen et al, 2014; Pion, Fransen, Lenoir et al, 2014; Opstoel, Pion, Elferink-Gemser et al, 2015), standing in contrast to the well-known profiling methods for talent detection. Not only do these generic tests make it possible to discriminate between potential elite and sub elite athletes (volleyball: Pion, Fransen, Deprez et al, 2014), they also allow to orient talents towards different sports (to date 9) (Pion, Segers, Fransen et al, 2014). As expected the more athletes are trained the more it is possible to distinguish sport specific profiles even for sports with overlapping characteristics (Pion, Fransen, Lenoir et al, 2014). On the other side of the continuum it was demonstrated that children with less training had less pronounced profiles (Opstoel, Pion, Elferink-Gemser et al, 2015).

SPORT SPECIFIC PROFILES IN PRIMARY SCHOOL CHILDREN

The first study aimed at investigating to what extent primary school children participating in a specific sport already exhibit performance characteristics in line with the requirements of six groups of sports (Ball sports, Dance, Gymnastics, Martial arts, Racquet sports and Swimming). This is in line with Gimbel (1976) and Montpetit & Cazorla (1982) who suggested that performance characteristics could be applied for talent prediction. In addition, the profiles in children with a different training volume were compared and possible differences in training hours per week between children from a low, moderate, and high level of physical fitness and motor coordination were investigated. The study showed that in general, children at a young age do not exhibit sport-specific characteristics, except in children with a high training volume, this is partly the result of what Ericsson (1993) called deliberate practice. It is possible that on the one hand, children have not spent enough time yet in their sport to develop sport-specific qualities. On the other hand, it could be possible that they do not take individual qualities into account when choosing a sport.

SPORT SPECIFIC PROFILES IN FLEMISH ELITE SPORT SCHOOLS

The aim of the second study was to evaluate that the generic test battery would have sufficient discriminant power to allocate athletes of the Flemish elite sport schools to their own sport based on a unique combination of test scores. This prospective study was in line with Csikszentmihalyi et al. (1993) and focused upon what makes gifted athletes unique and what contributes towards a sports career. De applied linear predictive models classified almost all participants correctly in their respective sport. The results of the discriminant analyses were even better than the study of Leone and collaegues (2002). It was also remarkable that the generic 'irrelevant?' characteristics have an important contribution when distinguishing between different sports. Fewer athletes were classified correctly within their respective disciplines when only focusing on relevant performance characteristics described in literature. The 'less' relevant 'generic' characteristics however showed additional power in discriminating sport specific profiles.

SPORT SPECIFIC PROFILES IN RELATED SPORTS

The third study aimed at discriminating related sports. The design of the previous study was applied in order to determine if the generic test battery also could allocate athletes in three different combat sports. Furthermore, it was expected as demonstrated by Harre (1982), that due to training and experience, differences between sports would be larger in the oldest age group. The classification results for both discriminant analyses U13 and U18 showed a perfect classification (100%) of the athletes in their respective sports. Generic talent characteristics allow for a successful discrimination between judo, taekwondo and karate athletes, while the differences between the martial arts profiles are more pronounced in older athletes. It was demonstrated that the importance of the talent characteristics differed in both age groups, which is in line with the sliding population approach from Régnier (1993) and with the presented framework to explain expert performance as result of extensive engagement in relevant practices (Ericsson et al., 1993)

PREDICTING ELITE PERFORMANCE

In the fourth study it was hypothesized that differences would be found in elite and sub-elite level female volleyball players using a retrospective analysis of generic test results gathered over a five-year period. Trainers and coaches rely on the evaluation of trained aspects and in previous volleyball studies it was found that stature and jump height are prerequisites for talent identification (Lidor & Ziv, 2010; Rikberg & Raudsepp 2011). In addition to the investigations in this field, we found that motor coordination is an important factor in elite volleyball. This study highlights the assessment of potential or in a broader perspective the assessment of characteristics closer related to 'nature' i.e., for which one has not trained. These generic tests are additional to the well-known performance tests that specify the training status, which we perceive as characteristics closer related to 'nurture'.

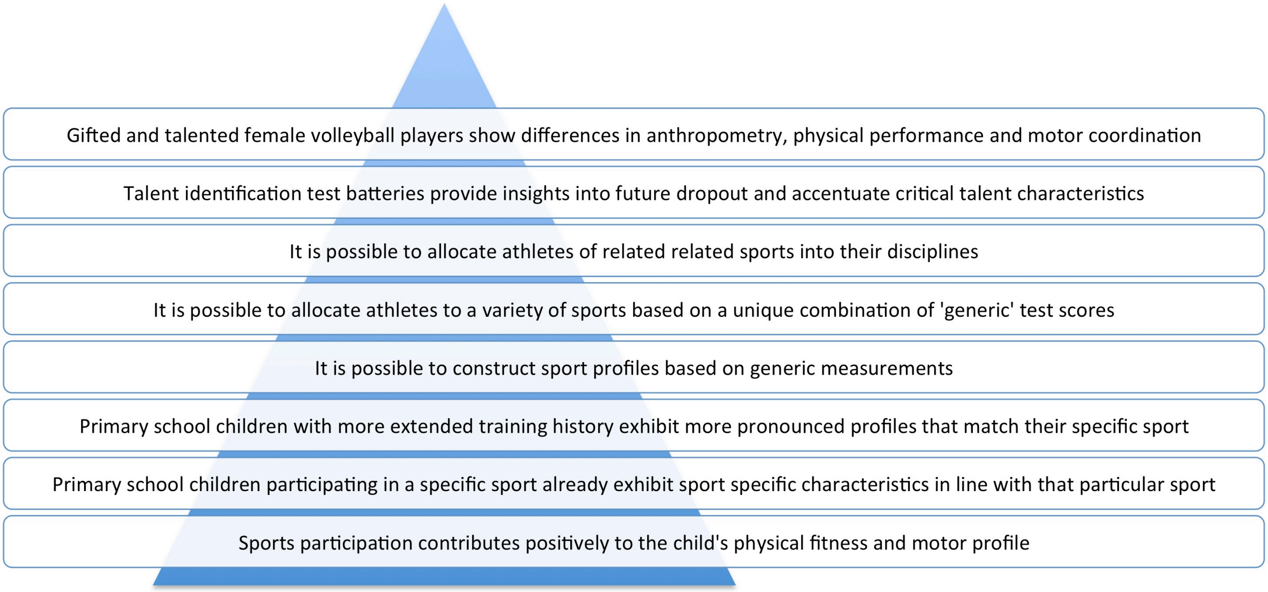
PREDICTING SURVIVAL IN ELITE SPORTS

The fifth ‘retrospective’ study investigated the link between the results of a talent identification test battery and attrition in female gymnastics. Kaplan-Meier and Cox Proportional Hazards analyses were conducted to determine the survival rate and the characteristics that influence dropout respectively. The results suggest that tests batteries commonly used for talent identification may also provide valuable insights into future dropout. These results can be integrated in the Athlete Development Triangle (Gulbin et al., 2010) to map the dropout towards elite level. The high dropout rates results should encourage trainers to invest in an early development of basic physical and motor characteristics to prevent attrition.

THE COSTS AND RISKS OF TALENT IDENTIFICATION

The sixth study highlighted the costs and risks of talent identification. Prospective research is difficult and yet there is a lot of dropout. The use of advanced predictive models for talent selection can avoid de-selection of high potential athletes. More accurate selection procedures supported by artificial intelligence results in less risk to de-select high potentials and consequently lower cost, which implies a different distribution of the resources that enhances better training facilities.

3.1.2 HYPOTHESES AND CONCLUSIONS



Gifted and talented female volleyball players show differences in anthropometry, physical performance and motor coordination

Talent identification test batteries provide insights into future dropout and accentuate critical talent characteristics

It is possible to allocate athletes of related related sports into their disciplines

It is possible to allocate athletes to a variety of sports based on a unique combination of 'generic' test scores

It is possible to construct sport profiles based on generic measurements

Primary school children with more extended training history exhibit more pronounced profiles that match their specific sport

Primary school children participating in a specific sport already exhibit sport specific characteristics in line with that particular sport

Sports participation contributes positively to the child's physical fitness and motor profile

Figure 36: Outline for the original research and hypotheses

PERFORMANCE CHARACTERISTICS

Training inevitably shapes the individual profiles and it is important to know whether sport-specific profiles are distinctive enough for different age groups and athletic levels. The different studies in this dissertation accentuate different aspects of generic performance characteristics. The main aim of the first study was to examine whether primary school children (9 to 11 year old) already involved in sports participation demonstrate sport-specific characteristics in terms of anthropometry, physical fitness and motor coordination. The second study predicted the sports participation in gifted athletes from Elite Sports Schools in Flanders. It was even possible to discriminate fighting sports athletes using generic performance tests. The total spectrum from beginner to medallist was assessed because in the fourth study, the differences between gifted and talent female volleyball players (the bronze medallists at the European championships) with the same development trajectory were studied. The development of talented athletes has also a negative connotation of dropout. In the fifth study it was demonstrated to what extend performance characteristics influence attrition. The final study accentuated the risks and costs of talent selection based on performance characteristics.

Hypotheses and Conclusions

(H_1) Sports participation contributes positively to the child’s general physical fitness and motor profile.

(C_1) The assumption that a more extended training history leads to more pronounced sport specific characteristics was supported by the results of the discriminant analyses in the different studies. Indeed, the primary schools study showed that in 85.2 % of the cases, the high active children who spend 5 or more hours per week in their sport were correctly assigned to their proper sport based on their anthropometric, physical fitness and motor coordination profile. In contrast, when considering low active children who spend not more than 1 hour per week, less than half of the children (48.4 %) were correctly allocated. Ericsson's theory of deliberate practice states that the level of expertise obtained by elite athletes is at least in part a function of the amount of structured practice. Our third study that discriminated judo, karate and taekwondo athletes focused on two age groups in which the importance of sport specific characteristics became more specific and shifted from motor coordination to more trainable characteristics i.e. speed and flexibility. When compared to their younger counterparts, judo athletes had the highest scores for sit and reach, handgrip, counter movement jump and balance beam. While taekwondo athletes had the highest scores for sit-ups, sprint 5m and 30m and jumping sideways.

(H_2) Primary school children, 9 to 11 year old, who are participating in a specific sport, already exhibit performance characteristics in line with the requirements of that particular sport.

(C_2) The first study in untrained primary school children showed that those youngsters do not present sport-specific physical characteristics except in children with a high training volume. This finding was confirmed in the third study. It was shown that generic talent characteristics allow for a successful discrimination between judo, taekwondo and karate athletes, while the differences between the martial arts profiles are more pronounced in older athletes.

(H_3) Children with a more extended training history exhibit more pronounced anthropometric, physical fitness and motor coordination profiles that match their specific sport characteristics.

(C_3) The first study conducted with the primary school children also demonstrated that, regardless of the type of sport, children with the best physical fitness and motor coordination characteristics are the ones who train the most hours per week. There were few differences between the six groups of sports. However, these differences do not entirely correspond with the sport-specific profiles assessed in trained young children as was noticed in the third study with the more pronounced profiles due to sport specific training.

TALENT ORIENTATION

The assessment of the differences between normal developing children and the 'better movers' is the first step in talent search. This phase can also be employed to suggest specific sports based on performance characteristics that meet the requirements for that sport. Because of the lack of uniformity in tests used to assess physical performance across and between sports, there is a need for a broad generic test battery, which will in turn accentuate the differences between sports. The generic test battery i.e. the Flemish Sports Compass is central to the studies in this dissertation and allows cross comparison between sports.

Hypotheses and Conclusions

(H_4) It is possible to construct sport profiles based on generic measurements and to compare them in children with a low, moderate, and high training volume.

(C_4) The study conducted in the primary schools showed that in general, children at a young age do not present sport-specific physical characteristics except in children with a high training volume. In contrast to elites, adolescent athletes who often dedicated years and years of training to their sport, the children within the study in the primary schools (9 to 11 years old) have not spent enough time yet within their sport to demonstrate sport specific characteristics. On the other hand, the study conducted in the Flemish elite sport schools revealed that adolescent athletes from different types of sports could clearly be distinguished based on their performance profile.

(H_5) It is possible to allocate athletes to a variety of sports based on a unique combination of test scores, using a non-sport specific generic test battery.

(C_5) The Flemish Sports Compass assessed in the Flemish elite sport schools confirms that elite adolescent boys show differences in generic talent characteristic that distinguish them according to their particular sport. The study revealed that it is possible to discriminate elite adolescents, using a test battery that uses non sport-specific tasks into the sport that best suits their specific anthropometric, physical and motor coordination profile. The test items used in the Flemish Sports Compass were able to differentiate gifted athletes in nine sports i.e. badminton, basketball, gymnastics, handball, judo, soccer, table tennis, triathlon and volleyball. It was demonstrated that the Flemish Sports Compass had sufficient discriminant power to allocate athletes to their own sport based on a unique combination of test scores.

(H_6) It is possible to allocate athletes of related sports into their specific discipline.

(C_6) The main finding of our third study was that generic talent characteristics allow for a successful discrimination between judo, taekwondo and karate athletes. In both age groups, 100% of the athletes were correctly classified in their respective sports. Discriminating fighting sports might be more problematic due to the similarities between the three martial arts, but the perfect classification rate in our study for both age groups aligned with our hypothesis.

PREDICTING PERFORMANCE AND SURVIVAL IN SPORTS

The Flemish Sports Compass is a scientific tool, which allows predicting potential performances. This dissertation contains three retrospective studies predicting performance or attrition of elite athletes several years in advance. The first study analysed test results five years in the past to assess differences in anthropometry, physical performance and motor coordination between Belgian elite (i.e. talented players) and sub-elite level female volleyball players (i.e. gifted players). The second and third study will be discussed in the sections in which survival of potential athletes and risk of talent selections are dealt. Physical performance tests are the tools for talent identification in different sports. Generic performance characteristics are widely used in talent detection and talent identification programs. In addition to these generic performance tests, investigators from our department introduced motor coordination tests as an important aspect in the talent detection and talent identification test batteries (Vandorpe et al., 2011; Vandendriessche et al., 2012; Fransen et al., 2013 and Deprez et al., 2013).

While test batteries are important for talent identification, they may also be useful for identifying dropout. The statistical technique applied in the fifth study in this dissertation is rather clinical and refers to medical analysis to predict the survival and hazard rates of patients. Due to the high dropout rates in elite sports it is possible to conduct this specific statistical technique, which allows to trace the underlying performance characteristics responsible to predict survival in elite sports.

In many countries talent identification programs are installed in an attempt to spend available resources more effectively. Prediction of future performance is difficult and featured by a significant dropout, which entails superfluous expenses. The last retrospective study in this dissertation focuses on the selection of gifted athletes based on the assessment of performance characteristics, five years prior to status of competition participation at the highest level in Flanders (A-level). We studied to what extent different predictive models have the potential to optimize selection procedures, and at the same time reduce talent development costs in sports.

Hypotheses and Conclusions

(H_7) Talent identification test batteries provide insights into future dropout and accentuate critical talent characteristics.

(C_7) The Cox Proportional Hazards Model applied in the fifth study of this dissertation indicated that gymnasts with a score in the best quartile for a specific characteristic significantly increased chances of survival by 45% to 129%. These characteristics being: basic motor skills (129%), shoulder strength (96%), leg strength (53%) and three gross motor coordination items (45% to 73%).

Therefore, test batteries deserve a prominent place in the selection process, since they also provide valuable insights into future dropout. The individual test results should encourage trainers to invest in an early development of basic physical and motor characteristics to prevent attrition. The baseline results become more exigent for each year that gymnasts continue their sport. The survival study stated that the more the analyses return in time, the less false positives and false negative respondents were wrongly classified. Respectively, after 3 years 69%; after 4 years 79% and after 5 years 88% of the gymnast were classified correctly as survivor or dropout by means of a linear predictive model i.e. discriminant analysis. In the sixth study, we investigated different selection methods compared to the prediction of the survival in female gymnastics. The results of different predictive models were compared with the results of the prior decisions made by the coaches at baseline. To reduce the risk of missing high potential athletes and in order to reduce the costs, it is important to adapt different methods. Data mining techniques showed their importance and therefore it is important to continue with the same talent identification test battery resulting in more resources for a better talent development program for fewer athletes.

(H$_8$) Gifted and talented female volleyball players show differences for anthropometry, physical performance and motor coordination.

(C$_8$) The main findings were that high-level players (i.e. talented players) had better motor coordination compared with average-level players (i.e. gifted players). It was expected that talented players, that finished in third place in the 2013 European Championships in Germany and Switzerland, however, would have different anthropometrical, physical performance and motor coordination scores than sub-elites. The fourth study in this dissertation reveals that only motor coordination scores were different between both playing levels. This might be due to the homogeneity of the group studied because all volleyball players had been pre-selected for top-sports academies based on their stature and physical performance. The assumptions that motor coordination tests discriminates the ‘better movers’ from their peers and provide important information about the potential of an athlete were confirmed. The results of the volleyball study show that motor coordination is an important factor in determining who makes into the elite level (Pion et al., 2014). It is interesting that measures that are most distantly un-related to volleyball were found to be the most significantly different. While jumping is certainly important, walking backwards and moving sideways seemed to be more important to predict the potential of the talented players (i.e. the medallists).

Summarizing the whole chapter we can state that the Flemish Sports Compass is a generic test battery that provides different science-based statements from talent detection to elite performance prediction. The different hypotheses illustrate that there is a skipped phase and a missing link in talent search (Figure 37). Indeed, talent orientation may be deservedly considered to be the missing link and an alternative to de-selection.

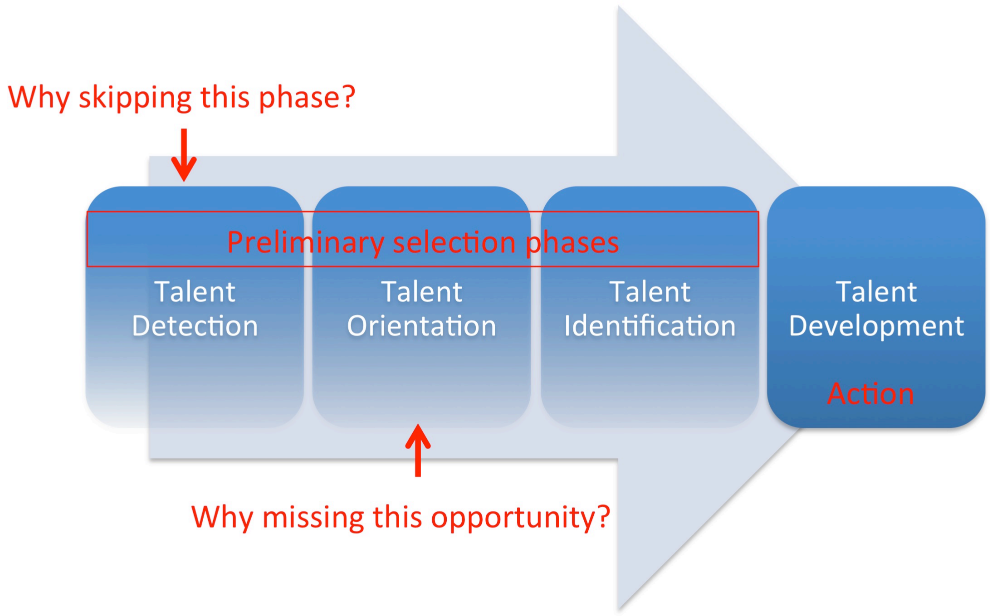


Figure 37: The missing link between Talent Detection and talent Identification

3.1.3 SCIENTIFICALLY BASED REFLECTIONS

NATURE - NURTURE DEBATE

The dilemma regarding whether or not innate giftedness is an important component of performance has been of interest for many decades. Within the field of sports science, elite performance is understood to be the result of both training and genetic factors. However, the extent to which champions are born or made is a question that remains one of considerable interest, since it has implications for talent identification and management, as well as for how sporting federations allocate scarce resources towards the optimisation of high-performance programmes (Tucker and Collins, 2012).

Talent characteristics can be placed in different layers. The first layer represents the performance characteristics, which are mostly assessed in sports practice. Whether strength, endurance or flexibility is innate or trained is not always clear at this level. Indeed, the measurements do not clearly indicate whether someone has trained or has the potential to perform in the future. The second layer comprises the body characteristics and influences the measured performance characteristics of the first layer. Complex measurements such as VO2max or Muscle Fibre Composition indicate why athletes can run faster or why they are stronger or have more endurance than their opponents. In this second layer the measured body characteristics are more complex to change or train. These measurements clearly indicate why somebody can grow or drop out and to what extend somebody is trainable. The information provided by the characteristics in this second layer allows facing the limitations of an athlete. It looks as if the proportion of nature defines the possibilities of what is possible for nurture. The third layer goes even deeper in the natural abilities with DNA investigations to map the performance characteristics of an individual. DNA analysis can point to exceptional or pathological conditions (Breitbach et al., 2014). Many concerns in the current talent research have gained attention in conventional and genetic testing. On the one hand, the tests being applied for the assessment of talent characteristics rely on reliable and valid measurements methods of complex performances. On the other hand, genetic testing has been supposed to serve in the risk stratification for the participation in high-performance sports instead of talent identification. There is increasing evidence for strong genetic influences on athletic performance and for an evolutionary “trade-off” between performance traits for speed and endurance activities Yang et al. (2003). Although, in genetic testing many studies show conflicting results due to different methods, different sports and different criteria. Furthermore, which information can provide the most accurate information, single gene mutations or a complex gene pool? The idea of gene testing is source of controversy, with supporters viewing it as a new frontier in sports science and critics saying it presents a labyrinth of complicated legal, moral, and ethical issues. The influence of natural gifts is more complex to measure in the first layer (performance characteristics) than in the second layer (body characteristics) and the third layer (DNA mapping). In addition training is most effective on the first layer of characteristics.

Nature refers to the innate ability to excel within a sport while nurture means developing skills through an extended amount of high quality training (Davids et al., 2007). Howe et al. (1998) rely on the position that if innate giftedness exists than this talent would be detectable at an early age. Their tenant is that if early, predictive detection of talent is lacking, then talent must not exist, and therefore, only training, motivation and self-confidence can explain expert performance. Others disagree. Rose (1995) stated that people inherit dispositions, not destinies. However it appears that until a direct connection can be verified between genetic predispositions and sport performance, the debate will continue Johnson & Tenenbaum (2006). It is not presently possible to ascertain the exact relative contribution of either genes or training to elite sporting performance, and it must be recognised that it is likely that the relative importance of training may differ for different sports, such that in some sports, genetic factors may be more significant (Tucker and Collins, 2012).

The literature on genetics supports both concepts of innate giftedness and environmental influence on expertise in sport. Research in the areas of twins and adoption, behavioural, cognitive, physical, physiological, maturational, and gene-environment interactions and correlations relate to the development of expertise in sport (Johnson & Tenenbaum, 2006).

The early estimates of heredity claimed up to 90% of the aerobic endurance (VO2max) to be innate (Klissouras, 1971). Today, only 50% of the aerobic endurance is attributed to genes (Hopkins, 2001). Since heredity of certain characteristics turned out not to be as important as previously thought, science examined the stability of performances over the course of the motor development and the training history of young athletes. Bouchard et al (1997) are leaning toward the direction that not only different abilities and traits but more important the trainability of the athlete itself is the most important innate factor. These authors distinguish between high and low responders according to their inherited responsiveness to training. Hohmann & Seidell (2003) conclude that heredity may play the same important role as nurturing one's talent in mono-structured sports, i.e. sports that depend on very few characteristics. In all other sports, in those where information-processing abilities come into play, the role of deliberate practice remains dominant (Baker 2001)

To prevent that the advantage that an innate ability goes to waste it might be of great interest to consider performance characteristics, before starting exigent training programs, when choosing a sport (Opstoel & Pion et al., 2015). Therefore it is important to implement a detection phase in talent projects. The difference in sport specific profiles between children who have benefited from a different amount of training hours can be associated with the concept of nurture. The more hours per week a child spends within the sport (= nurture), the closer it gets to exhibiting more pronounced sport specific characteristics as was demonstrated in our combat sports study that was conducted in two age groups. An extended training history is not only associated with more pronounced sport specific characteristics; it is also related to better physical fitness and motor coordination qualities.

The results of the first study indicated that the children with a better physical fitness and motor coordination profile spend more hours per week in their sport compared to the children who are not quite as strong physically and coordinatively. This is supported by a study of Fransen and colleagues (2012) who found a positive effect of the amount of training hours per week on the level of physical fitness and motor coordination in 10 to 12 year old boys. Boys who spent few hours per week (<4 hours) in their sport showed poorer motor coordination, flexibility and jumping capabilities compared to boys who spent many hours per week (>4 hours). To optimize the process of talent identification, children should be supported in choosing a sport that matches their personal characteristics. The talent detection phase has not only as a function to distinguish between gifted and less gifted children, but more importantly the opportunity to orient children towards a sport that matches with their individual performance profile.

THE QUALITY OF THE TALENT POOL

The argumentation that talented athletes always end up in the right sport is shortsighted. The main problem is that children and their parents are not always aware of the available talents. It would be easy if talent should be detected automatically. This is not the case and, moreover, talent identification in a sports federation is only possible when athletes are affiliated. It is important to notice that the quantity of the talent pool derives benefits from the accesability of the sport, which is positive because of the increased interest in sports. Gagné (2004) mentioned that within the DMGT-model the limits were set at 1 in 10,000 who are exceptionally gifted and 1 in

100,000 who are classified as extremely gifted. The quality of the talent pool however, is essential in the long run. Most trainers base their selecetions on the results of the sample that has been tested. They rarely ask themselves whether the tested a good cohort or not. Although, it is important to notice that the quality decreased the past decades due to sedantarism and alternative leisure activities. Vandorpe et al. (2011) indicated that the motor competence decreased by 50% in the category of well-performing primary school children (Figure 38). In addition, similar results were found in a representative sample of Flemish 3-8 year old preschoolers by Bardid et al. (2014).

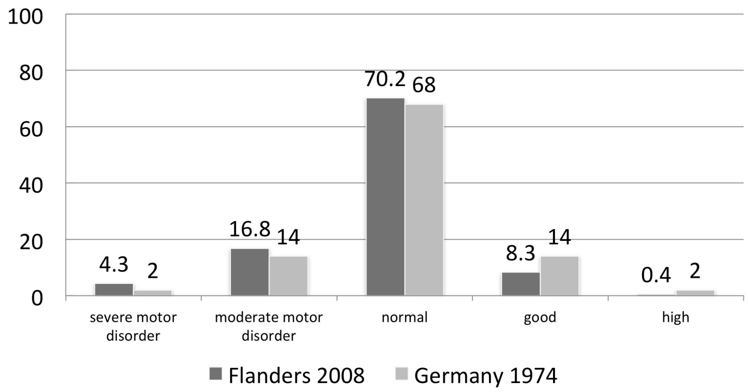


Figure 38: Comparison of MQ-scores for KTK between primary school children in Flanders 2008 and Germany 1974 (Vandorpe et al., 2011)

Vandorpe and collaegues (2011) concluded that the talent pool in Flanders is small and that the quality deteriorated considerably. Consequently we can state that talent is to scarce to spoil and that talent projects are a necessity for both, the individual and the sports federations.

SLIDING POPULATION APPROACH

The coordination between different test batteries is essential to get the most information during the development of talented athletes. Currently al the tests are administred seperatly and it is always problematic to find the relations between different assessments. Régnier’s sliding population approach (Régnier 1993) takes into consideration the different stages of performance and our findings are in accordance with the proposition that anthropometric and physical characteristics become more important as athletes grow older and reach a higher performance level due to training and ‘natural’ selection. Our third study also highlighted the special demands for the training of children and adolescents. The differences between the martial arts become more pronounced with age. Furthermore, it was found that already before adolescence junior athletes present the necessary anthropometrical, physical and motor coordination characteristics to excel in their sport revealed that certain accents in regard to athletic performance in fighting sports are necessary for different age groups.

The content of the testbattery is of importance for the follow-up towards the next assessment that indicates that an athlete is on track. Our survival study stated that anthropometric, physical and motor coordination characteristics differ between gymnasts continuing at a high level and gymnasts dropping out from competition 3, 4 and 5 years after baseline measurement. The threshold scores for the survivors increased year after year suggesting that the baseline results are more exigent for each year that gymnasts continue their sport. The more the analyses return in time, the less false positives and false negative respondents were wrongly classified. Respectively, after 3 years 69%; after 4 years 79% and after 5 years 88% of the gymnast were classified correctly as survivor or dropout by means of a linear predictive model i.e. discriminant analysis.

The value of the content differs with age, which is in line with the sliding population approach of Régnier (1993) and the LTAD-model of Balyi and Hamilton (2004) who argue to take into account the various stages of development. In our studies it was demonstrated that the motor coordination tests provides essential information for future development. Therefore, it seems logical that a motor assessment is necessary in the phase of talent detection. The same tests can be used for talent identification to track the progress of each individual. The motor tests will be replaced by technical assessments when technique becomes more important. We highlighted the value of retrospective analytics in our volleyball study and advocate to always evaluate new test results in the context of the previous test results, even if other methods or techniques were applied. To optimize the interpretation of the different assessment it should be considered for implementing a cascade system from interconnected test batteries with an emphasis on the talent characteristics that are important at a certain moment during the 'individual' development phase. The multiple advantages of continuos measurements that are well coordinated provide opportunities for small countries or regions.

ORIENTATION AS AN ALTERNATIVE FOR DESELECTION

Gulbin (2009) advocated for second-chance opportunities for athletes by stating that there may be many post-puberty athletes who do not achieve expertise or who leave their sport due to age, injury or de-selection, but still possess physiological capacities and skills that can be used in other sporting disciplines (Gulbin, 2009). This concept was adapted by many nations who started with talent transfer programs. It has been showed that talent transfer is feasible in a short-term policy. Before switching to a second chance a first chance should be offered. Unfortunately, talent orientation is a long-term project and therefore less popular to invest in. No arguments are needed to promote talent orientation instead of de-slection in a single sport. Especially since de-slected athletes have difficulties to come back to the level of the selected athletes (Tucker, 2014). The de-selected athletes can be subdivided into negative and false negative responders of an assessment. At baseline it is not possible to devide the de-selected athletes into these two groups. Only retrospective analyses can prove that an athlete was wrongly de-selected. Therefore, the alternative of talent orientation is a better option to avoid early dropout.

BENEFITS OR COSTS

National governments invest substantial amounts of money in talent identification and promotion programmes. Although traditional talent identification and talent promotion is characterized by relatively large numbers of recruited athletes, high expenses over long periods, low success rates, and uncertain programme effects, mature-age talent identification and talent recycling programmes may be associated with fairly low numbers of promoted individuals, much shorter support periods, and apparently higher success rates. Furthermore, from a funding body's perspective, a scholar- ship athlete who could not deliver the expected sporting success does not necessarily have to be labelled a ''waste of money'' if this athlete's skills can be reallocated to another sport. (Vaeyens et al., 2009). The implementation of a detection phase in the primary schools is a first step towards a sliding population approach. The strength of the system lies in the involvement of various actors. P.E teachers and the coaches in the clubs are the cornerstones to support a joint project. Talent orientation allows detecting gifted children without the negative connotation of de-selection and a (false) labeling of the primary school children. A motivated choice reduces the cost and the efforts in the first phase of talent development. The talent identification programs in the different sports federations can benefit from a global initiative that motivates the children to practice one or more sports. According to Coté and Vierimaa (2014), the nurturing of talent through diverse sports activities without an intense focus on performance in one sport, during childhood can have more positive and less negative consequences for all children involved in sport, while still facilitating the long-term development of elite performance. Policy makers can stress the partnership between PE teachers and sports trainers by highlighting the importance of a professional guidance in a broad sports development of young children. A coordinated cooperation can benefit for a better motor coordination. PE teachers are best placed to support a choice based on what children like to do, which will keep them involved in sports.

3.1.4 RECOMMENDATIONS FOR POLICY MAKERS

ENCOURAGE A BROAD DEVELOPMENT

During the first stage of athletic development, Coté et al. (2009) propose a combination of deliberate play and the sampling of different sports. This might help to create a broad basis of fundamental skills needed to progress to specialized training in one sport. Fransen (2014) stated that relatively older (10 - 12 years) boys sampling different sports have better measures for physical fitness and motor competence than those children that specialize in just one sport. The afformentioned study did not provide empirical evidence for the superiority of early diversification over the early specialization pathway in any way. The notation that sampling more than one sport does not per se hinder specific performance confirmed Coté's DMSP (1999). Other sources (Hohmann, 2009) prefer a specialisation at a young age (i.e. 10 -12 year old boys and girls) in order to prevent for an aimless sports development that can turn into a dropout of talented children. Thus the best time to carry out the Flemish Sports Compass seems to be the age of 10 y after a period of broad development in all the sports clubs. Furthermore, sports clubs should be aware of the problems that arise with late mature girls and boys and integrate initiatives to prevent attrition because of a delayed physical development. The shadow teams for the Belgian national youth soccer teams are an example of a successfully implemented initiative where late mature players can develop on their own development pathway.

The existing talent models assume that a young person who is in a talent pathway possess the required characteristics that serve as a basis to create progress. Csikszentmihalyi and colleagues (1993) accentuated that the characteristics develop in different stages and therefore it is necessary to assess the correct mix for the correct age group. This is also in line with Régnier's sliding population approach (Régnier et al., 1993). In our martial arts study we assessed different age groups and proved that a mix of generic talent characteristics also differ with age. The last decade's different theses were postulated starting with deliberate practice (Ericsson et al., 1993) followed by deliberate play to achieve the best possible pathway towards elite level (Coté et al., 2009). Moreover, deliberate programming made it even possible to develop elite athletes in a short term (Bullock et al., 2009). The development path to be selected depends on the previous initiatives taken to select the better participants. The search for talented youngsters starts with the mostly forgotten detection phase. Indeed small countries should implement this phase, which coordinates the actions of different sports federations in their search for talent. The main aim is to enlarge the pool for different sports federations so that they can continue with the broad development of the most talented players.

PROMOTE GENERIC MOTOR COORDINATION FROM CHILDHOOD

The secular trend of decreased physical fitness (anthropometry and physical performance) was extensively documented during the last decades and also appears to manifest itself for motor coordination. There is evidence that the coordination is fixed at the start of the primary school age (Vandorpe et al., 2011). Consequently, different levels (Flemish federal governement, municipal governments, kindergartens, sports clubs sports federations, etc.) should be stimulated to offer more and varied movement activities to young children, or at least to create good conditions for adequate and varied movement opportunities. Stimulating the generic motor development at a young age can enlarge the pool of high potentials. In Flanders there is currently a broad initiative called 'Multimove' that focussess on the motor development of young children. The combination with the sampling of different sports at a young age and should be systematically included in talent detection and talent identification programs. Indeed the retrospective study in volleyball used anthropometry, physical performance and motor coordination scores, assessed five years prior to examine differences between international elite (talented, female volleyball players) and sub-elite (gifted, female volleyball players). The main findings were that the talented players had better motor coordination compared with the gifted players. It was expected that the talented group, however, would have better anthropometrical, physical performance and motor coordination scores. The fourth study in this dissertation revealed that only motor coordination scores were different between both playing levels. This accentuates the importance of the assessment of motor coordination to predict future successes. It is well known from previous research that stature and jump height are prerequisites for talent identification in female volleyball. The results in this study demonstrated that motor coordination is an important factor in talent prediction and confirms our hypothesis that motor coordination should be included in talent detection and talent identification test batteries.

PROVIDE A TALENT DETECTION PHASE

The place par excellence for early detection of gifted children is the primary school. According Platvoet et al. (2010) it is still a missed opportunity that physical education teachers do not detect the potential sports talents and pthat they possibly not provide the opportunity to orient children to one or more sports to develop their talents. In this study it was demonstrated that it was possible to a) detect the 'better movers' and b) to inform these children objectively about the sport(s) that meet(s) their individual profile with a relatively simple and generic test battery. Furthermore, it was shown that many Flemish children have a very well developed generic or even sports specific profile and that they were still not involved in sports participation. The Flemish Sports Compass provides an informative choice based on physical characteristics and the final decision on a sporting choice should be in accordance with the preference of the child and / or his parents. An early systematic advice based on an objective and generic test battery is valuable for children who are not extremely gifted in sports. The "Sports Compass" which is the result of the individual performance scores in the software application is indeed valid for every child, regardless of the level of the better move. It provides a relative relationship between sports that are more or less suited to a childs talent characteristics, and can ensure that the child is participating in that sport whit the highest succes rates, regardless of the absolute level to achieve.

The advice given by the physical education teachers who are involved at the basis of a large-scale project is the most important strength of the proposed talent system designed for small countries. Direct communication between a confidential counselor, children and parents is possible in the schools which not only offers opportunities to screen all the children, which accelerates the flow towards organized sports. Coordination and belief in the project are crucial points in the presented system. The benefits should be sufficiently be known by all stakeholders. The transmission of information from school to club has to be facilitated by a coordinating body. A national coordinated database system can direct children towards the most appropriate sport based on their individual profiles. This will provide an additional tool for the policy makkers, which can help the sports federations in the quest for talented children for their sport, by detecting the children who are not yet involved in a specific sport. The proposed system is based on generic tests and brings toghether all the first steps of the talent systems in the participating sports federations. The difference with the actual existing 'jeugdolympiade' is that professionals i.e. the teachers make the first screening and that the data are available for succession. The second step can be a more specific screening, which is comparable to the three-steps talent system adapted in the UK (Laing, 2014), Australia (Eastwood, 2014) and in Qatar (Douglas, 2014). The Flemish Sports Coimpass distinguishes itself from the mentioned talent systems since al recommendations are based on performance characteristics (I Do) and preferences (I Like). Similarly, to the other systems, the best performers can be invited for the silver phase of a national coordinated talent identification system. The silver phase could be an opportunity for the different sports federations to attract potential athletes for their sport. A better solution seems to be provided by the Japanese Multi Sports Elite schools for a continued basic development that may be considered as the gold phase, which is applied in different national talent systems (Kinugasa, 2014).

A TALENT SYSTEM FOR A SMALL COUNTRY

Talent systems are useful. Although, for small countries the situation is different compared to the traditional countries that implemented succesfull systems. The UK and Australia skip the phase of talent detection and start with the phase of talent identification in different sports federations. The orientation from one sport towards another sport is designed for short time success in athletes that already show a high degree of training and is called talent transfer. Talent orientation is difficult to handle due to the complexity of the different sports federations with their own objectives. Furthermore, the chance to find an athlete is much larger in a large country than in the sport specific populations in small countries. The impact of missing an athlete is much more problematic in smaller populations and therefore it is important to collaborate between partner federations. The advantage that sports clubs are able to enlarge their pools by detecting high potentials that are not yet involved in a specific sport is in contrast with the fear for cannibalism between the sports federations. Indeed, sports federations make all possible efforts to attract as many members as possible to be involved in their sport, although when it comes to elite sport it should be clear that the sports federations have the responsability to direct the athlete towards the sport where the biggest success can be achieved.

An innovative talent system is necessary if small countries aim to compete with the traditional big countries. Small countries have the disadvantage of the smaller population in return they have the advantage to test every single child in the population. This does not necessarily mean that a sports detection system should cost huge amounts of money and efforts. A possible solution is the implementation of the talent detection phase in the primary schools. To succeed, coordination i.e. sports policy and cooperation i.e. the different partners are crucial. The combination of online questionnaires and practical assessments in the schools offers new perspectives in the search for talent. The collaboration between physical education teachers, sports workers in the municipalities, trainers and coaches in clubs will reduce the expences for all the fragmented efforts carried out in limited sport specific populations. Test batteries traditionally evaluate what children are good at; we suggest that it is important to measure what children like to do to keep them involved in sports. Within Gagné's DMGT only 1 child in 100 is called moderately gifted, 1 in 1000 is highly gifted or moderately talented, 1 in 10,000 is exceptionally gifted or highly talented and 1 in 100,000 is classified as extremely gifted or exceptionally talented. The problem is not only to find the exceptionally talented but to orient all the children towards a sport that fits with their needs and for a majority it is more important to choose for a sport based on their performance characteristics.

FLEMISH SPORTS COMPASS FOR ALL

It is possible that primary school children do not take into account their physical characteristics when choosing a type of sport. A review on children's motives for sports participation pointed out the influence of five motivational factors including perception of competence, fun and enjoyment, parents, learning new skills, and friends and peers (Cope et al., 2013). Fun and enjoyment is known to be one of the most important motives for children to participate in a sport (Chalip et al., 1998; Green 2005; Wankel 1985 and Weiss et al., 2008) revealed that it is possible that children do not choose a sport that matches their physical qualities in the age range from 9 to 11 but they make that choice based on how much they enjoy the sport. Indeed the tradition of measuring the strengths and weaknesses of young children is focused on the performance characteristics (I Do), while it is important for the main part of the children to make a sport choice based on what they like to do (I Like). When implementing the Flemish Sports Compass in 15 primary schools in Ghent, (November 2014 - March 2015), three different assessments were conducted. First, performance was measured by means of the

Flemish Sports Compass. Second, a pictorial scale was conducted to measure the sports preferences of the children (I Like). Third, a questionnaire provided valuable information for motivation and perceived competence (I Can). We presume that the extension of the Flemish Sports Compass with two components, which can be tested online, will attract children and their parents. In order to further document the value of general, non sport-specific motor coordination in talent identification in other sports, it is preferable to continue with this idea of a generic movement competency assessment.

3.1.5 TOOLS FOR TALENT RESEARCH

Sports science is more than theories and statistics. Therefore, the knowledge gathered from our different studies was translated into practical tools. The scientific data collection is necessary in order to establish a standard. These standards were set using different statistical methods that provided insights in the exceptional results of the gifted performers. The scientific approach was always translated into practical resolutions for the participants who always received their results compared to a specific benchmark (primary school, elite level, …). During the first years, raw scores were normalized for gender and age group to detect the ‘better movers’ in the primary schools. The different tools were developed in Filemaker Pro. The applications are easy to use yet a web application coulsd provide more opportunities. The same software was adapted to identify the better athletes in a certain sport. Indeed the data from the Flemish elite sport schools and from data obtained in the federations were applied to benchmark the individual results. The tools for all the different applications have their own accents yet for limited use it is possible to implement a flexible software package. Web based software sometimes requires a cumbersome database, which is not always the optimal solution to test out new opportunities for talent research, but which is very suitable for large-scale use. The talent detection and talent identification tools of the Flemish Sports Compass are ready for use on both platforms. The recent scientifical findings from the survival analysis and artificial neural networks were integrated in the benchmarks in Filemaker Pro (electronical addendum). To make predictions on the optimal player’s position in basketball traditional linear statistical techniques are not sufficient. More complex statistical analyses such as discriminant analyses are in place and have already shown their worth in predicting a player’s potential, in assigning elite athletes to the correct sport discipline (Pion et al., 2014). These DA are based on linear statistical models, but more recently non-linear techniques with artificial neural networks have shown to provide additional insight in the prediction on the position specific demands for basketball players (Stautemas et al., 2015). By means of descriptive statistics and the discriminating factors obtained by artificial neural networks (i.e. Multi Layer Perceptron) a tool was developed to distinguish the better players. The tool indicates the discriminating factors for that specific position. As such a trainer can see at first sight whether a player has the right physiognomy and the appropriate physiological characteristics and in case of doubt examine the most important factors. The presented basketball positions tool is a Filemaker Pro 13 application and provides a visual output, which can be interpreted immediately.

3.1.6 DIRECTIONS FOR FUTURE RESEARCH

The sports compass is based upon the sports from the Flemish elite sport schools and future research is needed to adopt new sports that wish to take part in a coordinated talent detection phase. It is also important to explore the responses of children, athletes, coaches and parents about the provided advice with the different tools. Future research should elucidate the usability for the individual respondents. It is important to investigate to what extent sport profiles will orient children and adolescents towards the sport that best matches their anthropometrical, physical and coordination profiles as a part of total tool with different possibilities i.e. I Do (performance) – I Like (preferences) – I Can (motivation). Besides the use as an identification tool it is also usefull in a way to acertain what an athlete is lacking, which in turn can help coaches to improve the training processes.

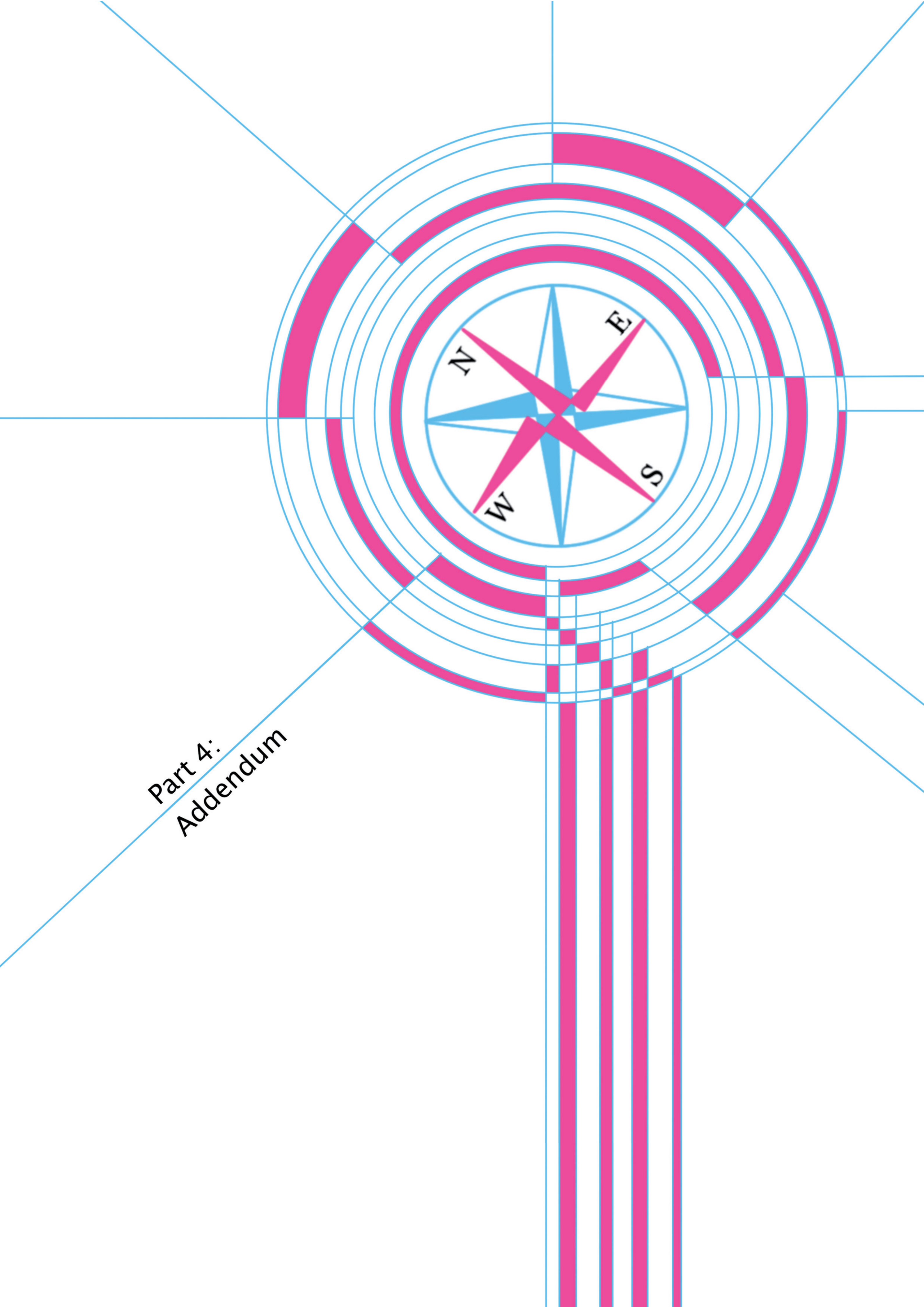
The limitation of relatively small sample sizes is inherent to research in less popular sports and little samples of trained athletes, who are not numerous by definition. Nevertheless, the generic talent characteristics included in our studies allowed for a successful discrimination between different sports. Continuing the data collection is a condition sine qua non for an optimal development of the database. The knowledge gained in connection with the use of data mining techniques should be further applied to valorize the investments made by different institutions in Flanders.

Though the test battery used in our studies was quite extensive, it is important to highlight that it is limited by the absence of psychological and environmental factors. The detection phase should be complemented with brief questionnaires to assess their motivation and how children like to move and how they perceive their competences. The lack of a psychological assessment might be more important in the talent identification phase, when athletes decide to start with a thorough training schedule. Although, considering the high dropout rate before reaching this point it seems plausible to invest in a brief assessment of psychological and environmental characteristics at a younger age to prevent early attrition. The tools are prepared and the Flemish Sports Compass has recently evoluated towards a multidisciplinary tool, which also takes into account the preferences (I Like) and the motivation (I can). The App's are in preparation although this is not any more the subject of this doctoral dissertation.

References

1. Balyi, I., & Hamilton, A. (2004). Long-term athlete development: Trainability in childhood and adolescence. *Olympic Coach*, *16*(1), 4-9.
2. Bardid, F., Huyben, F., Deconinck, F., Seghers, J., De Martelaer, K., & Lenoir, M. (2014). Motor competence assessment in young children: Convergent validity between the KTK and MOT 4-6 test batteries. *Science & Sports*, *29*, S20-S21.
3. Boone J, Bourgois J. Morphological and physiological profile of elite basketball players in Belgian. Int J Sports Physiol Perform 2013 November;8(6):630-8.
4. Bullock, N., J. P. Gulbin, D. T. Martin, A. Ross, T. Holland and F. Marino (2009). "Talent identification and deliberate programming in skeleton: Ice novice to Winter Olympian in 14 months." Journal of Sports Sciences 27(4): 397-404.
5. Chalip L, Green BL. Establishing and maintaining a modified youth sport program: Lessons from Hotellings location game. Sociology of Sport Journal 1998: 15 (4):326-42.
6. Cope EJ, Bailey R, Pearce G. Why do children take part in, and remain involved in sport? A literature review and discussion of implications for sports coaches. International Journal of Coaching Science. 2013;7(1):55-74.
7. Coté J. The influence of the family in the development of talent in sport. Sport Psychol 1999; 13: 395-417
8. Coté, J Lidor, R., & Hackfort, D. (2009). ISSP position stand: To sample or to specialize? Seven postulates about youth sport activities that lead to continued participation and elite performance. *International Journal of Sport and Exercise Psychology*, *7*(1), 7-17.
9. Côté, J., & Vierimaa, M. (2014). The developmental model of sport participation: 15 years after its first conceptualization. *Science & Sports*, *29*, S63-S69. Csikszentmihalyi M., Rathunde K., Whalen S., (1993), Talented teenagers: The roots of success and failure. New York: Cambridge University Press.
10. Davids K, Baker J. Genes, environment and sport performance: why the nature-nurture dualism is no longer relevant. Sports medicine. 2007; 37(11):961-80.
11. Deprez, D., Valente-dos-Santos, J., Silva, M. J., Lenoir, M., Philippaerts, R., & Vaeyens, R. (2014). Multilevel Development Models of Explosive Leg Power in High-Level Soccer Players. *Medicine and science in sports and exercise*.
12. Douglas (2014) Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014 “Sifting the sands – Talent identification at Aspire Academy. Qatar.”
13. Eastwood 2014 Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014 “Talent Identification in South Australia. Challenges, interventions and successes”
14. Ericsson, K. A., Krampe, R. T., & Teschromer, C. (1993). The role of deliberate practice in the aquisition of expert performance. *Psychological Review, 100*(3), 363-406.
15. Fransen, J., Pion, J., Vandendriessche, J., Vandorpe, B., Vaeyens, R., Lenoir, M., & Philippaerts, R. M. (2012). Differences in physical fitness and gross motor coordination in boys aged 6–12 years specializing in one versus sampling more than one sport. *Journal of sports sciences*, *30*(4), 379-386.
16. Fransen, J., Deprez, D., Pion, J., Tallir, I. B., D'Hondt, E., Vaeyens, R., ... & Philippaerts, R. M. (2013). Changes in Physical Fitness and Sports Participation Among Children With Different Levels of Motor Competence: A Two-Year Longitudinal Study. *Pediatric exercise science*.
17. Gagné (2004) *Transforming gifts into talents: the DMGT as a developmental theory. High Ability Studies, 2004. 15(2): p. 119-147.*
18. Green BC. Building sport programs to optimize athlete recruitment, retention, and transition: Toward a normative theory of sport development. J Sport Manage. 2005;19(3):233-253.
19. Gimbel B. (1976). Possibilities and problems in sport talent detection and research [in German]. Leistungssport 1976; 6: 159–67
20. Gulbin, J. P., & Ackland, T. R. (2009). Talent identification and profiling. *Applied Anatomy and Biomechanics in Sport, Champaign IL, Human Kinetics*, 11-26.
21. Gulbin, J., Oldenziel, K., Weissensteiner, J., & Gagné, F. (2010). A look through the rear view mirror: Developmental experiences and insights of high performance athletes.
22. Harre D. (1982). Trainingslehre. Berlin: Sportverlag
23. Hohmann A. (2009). Entwicklung Sportlicher Talente an Sportbetonten Schulen, Shwimmen-Leichtathletik-Handball, Michael Imhof Verlag Gmbh&Co.KG, Petersberg

24. Kinugasa (2014) Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. “Targeting Tokyo 2020 and beyond/ The Japanese TID model”
25. Laing (2014) Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. 3 To the London Olympics and beyond – talent identification practices in the UK”
26. Leone M, Lariviere G, Comtois AS. Discriminant analysis of anthropometric and biomotor variables among elite adolescent female athletes in four sports. J Sports Sci 2002; 20(6): 443-449
27. Lidor R and Ziv G. Physical and Physiological Attributes of Female Volleyball Players-a Review. *J Strength Cond Res* 24: 1963-1973, 2010.
28. Montpetit R, Cazorla L, (1982). La detection du talent en natation, Revue de l'Entraineur 5: 26‐ 37
29. Opstoel K*, Pion J*, Elferink-Gemser M, Hartman E, Willemse B, Philippaerts R, Visscher C, Lenoir M. Anthropometric, Physical fitness and motor coordinative characteristics of 9 to 12 year old children participating in a wide range of sports. (2015) PlosOne.
30. Pion J, Segers V, Fransen J, Debuyck G, Deprez D, Haerens L, Vaeyens R, Philippaerts R, Lenoir M. Generic anthropometric and performance characteristics among elite adolescent boys in nine different sports. (2014). European Journal of Sport Science, Ahead of print, DOI: 10.1080/17461391.2014.944875
31. Pion J*, Fransen J*, Lenoir M, Segers V. The value of non-sport-specific characteristics for talent orientation in young male judo, karate and taekwondo athletes. (2014) Archives of Budo (10), p. 147-152
32. Pion J, Fransen J, Deprez D, Segers V, Vaeyens R, Philippaerts R, Lenoir M. Stature and jumping height are required in female volleyball, but motor coordination is a key factor for future elite success. (2014) Journal of Strength and Conditioning Research.
33. Platvoet S., Elferink-Gemser M., Visscher C. (2010). Sporttalent herkend, Lichamelijke Opvoeding n°5, mei 2010, KVLO Zeist, Nederland.
34. Régnier, G.; Salmela, J. en Russell, S.J. (1993). Talent detection and development in sport. In Singer, R.N.; Milledge, M. en Tennant, L.K. Handbook of research on sport psychology, 290‐313. New York: Macmillan Publishing company
35. Rikberg A and Raudsepp L. Multidimensional Performance Characteristics in Talented Male Youth Volleyball Players. *Pediatr Exerc Sci* 23: 537-548, 2011.
36. Stautemas J., Segers V., Pion J., Boone J., Lenoir M., Bourgois J. (2015). Predictive models for position specific performance profiles in elite basketball, International Journal of Sports Physiology and Performance, in review.
37. Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine*, bjsports-2011.
38. Tucker R (2014) Talent Identification Conference “Identifying Champions” April 2nd – 3rd 2014. “The talent equilibrium: Finding balance between scientific prudence and strategic prerogatives”
39. Vaeyens, R., Lenoir, M., Williams A. M., Philippaerts R. (2008). Talent identification and development programmes in sport ‐ Current models and future directions. Sports Medicine, 38(9): p. 703‐714.
40. Vaeyens R, Güllich A, Warr CR, Philippaerts R, (2009). Talent identification and promotion programmes of Olympic athletes. Journal of Sports Sciences, 27(13): p. 1367‐1380.
41. Vandendriessche, J. B., R. Vaeyens, B. Vandorpe, M. Lenoir, J. Lefevre and R. M. Philippaerts (2012). "Biological maturation, morphology, fitness, and motor coordination as part of a selection strategy in the search for international youth soccer players (age 15-16 years)." Journal of Sports Sciences **30**(15): 1695-1703.
42. Vandorpe, B., J. Vandendriessche, R. Vaeyens, J. Pion, J. Lefevre, R. Philippaerts and M. Lenoir (2011). "Factors Discriminating Gymnasts by Competitive Level." International Journal of Sports Medicine **32**(8): 591-597.
43. Wankel LM, Kreisel PSJ. Factors Underlying Enjoyment of Youth Sports - Sport and Age Group Comparisons. J Sport Psychol. 1985;7(1):51-64.
44. Weiss MR, Amorose AJ. Motivational orientations and sport behaviour. In: Horn TS, editor. Advances in Sport Psychology. 3 ed. Champaign, IL: Human Kinetics; 2008. p. 115-155.



Part 4:
Addendum

4.1 TIME PERIOD 1970 – 1979 (PERFORMANCE PREDICTORS)

Talent search in sports peaked in the second half of the 20th century with the heavily debated performance system of the former German Democratic Republic that was based on a systematic screening of all children. The scientific research cited that talent characteristics and its stability can be measured from a young age although; most authors (Wolkow, 1974; Gimbel, 1976; Harre, 1982 and Bompa, 1985) remained vague when describing the earlier talent identification in the former Eastern Bloc. The socio-economic status and the variation in biological development were observed as well, yet without indicating how to measure these characteristics. A disadvantage in the process of talent identification is that the selection of the high potentials is often also a de-selection of the less gifted. The only exception to the rule was the model of Gimbel (1976), which referred the de-selected candidates to opportunities within the sport for all. Gimbel was one of the earlier theorists who suggested that elite level performance required approximately 8 to 10 years of training. Geron (1978) proposed a model similar to Gimbel's (1976) and used the profiles of elite performers to help identify the relevant performance variables. Geron concluded that profiles of elite performers were not sufficient to predict talent, as there were differences between the early qualities required to become a champion and the actual qualities of a champion. Geron highlighted the distinction between the raw materials and systematically developed skills, which Gagné (1985) defined as “giftedness and talent”, respectively. Meanwhile, Wolkow (1974), Bar-Or (1975), Jones and Watson (1977) relied on subjective judgements in combination with objectively observed skills as the most important criterion for talent identification.

The multifactorial approach in order to detect and identify talent, combined with a longitudinal follow-up and multiple regression techniques was introduced in the seventies by different sports scientists (Wolkow, 1974; Bar-Or; 1975 and Geron, 1978). Bar-Or (1975) conceived a five step approach to talent detection, involving; (a) the evaluation of morphological, physiological, psychological and performance variables; (b) the comparison of data with a developmental index to account for biological age; (c) response to training; (d) family history; and (e) the use of a multiple regression analysis Durand-Bush & Salmela (2001) noted that Bar-Or's approach seemed plausible, however they also pointed out that the model was never tested within a longitudinal field study across sports.

Jones and Watson (1977) investigated the relation between predictors and performance. The used method was more suitable for sports with quantifiable criteria such as time and distance in athletics. Another model by Gabler and Ruoff (1979) was a complex top-down model in which the relationship between predictors and performance was investigated. However, their complex model was mainly based on the analysis of performance development rather than the search for talented athletes (Figure 39). The authors demonstrated that a stable talent characteristic is not to be confused with a stable relationship between the predictors and performance. The predictor problem suggests that the characteristics should have a predictive value, by being present at the selection age and by their stable evolution.

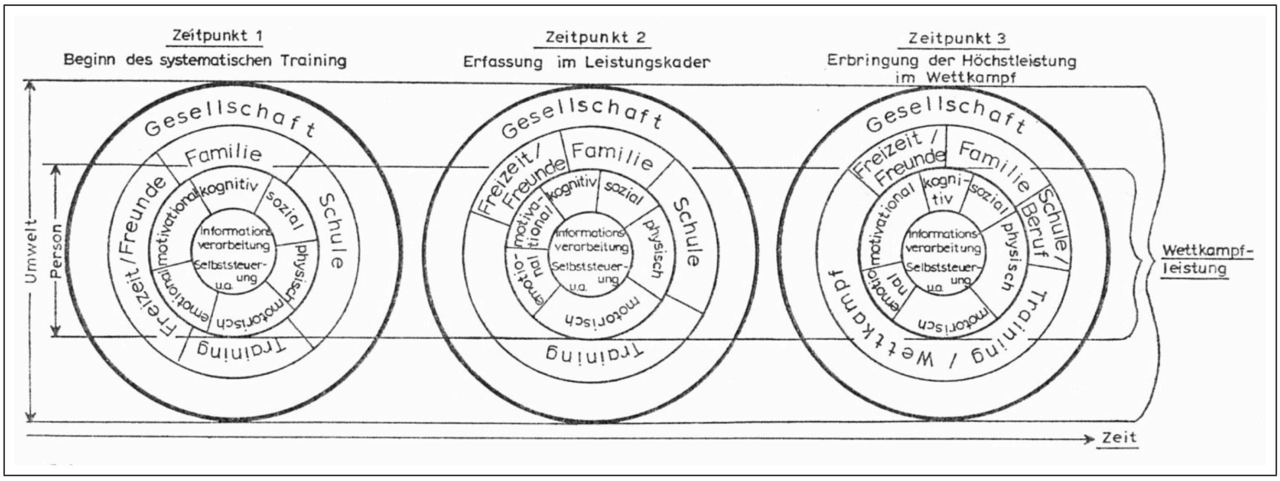


Figure 39: Representation of significant characteristics in different stages of athletic career (Gabler and Ruoff 1979)

Nationwide implemented Talent Systems

The successful talent identification system of the former German Democratic Republic (GDR) is the predecessor of different successful talent systems developed during the next decades i.e. the Australian Institute of Sport (AIS), UK Sports Performance Pathway Team, and the Talent identification Unit at Japan Sport Council.

There has been a lot of criticism of the talent detection, talent identification and talent development system from the former Eastern Bloc. Especially the GDR State Plan 14:25 (Hungermann, 2006) is the cause of a negative connotation of talent identification, partly because systematic doping was given to the athletes. Some components of the former GDR sport exhibited large costs, but not equivalent outcomes. The Eastern athletes specialised earlier in one sport, participated less in other sports, performed much more specialised training during youth and adulthood, and used athlete services more intensively. They attained greater early success during youth, but not greater senior success. The economic inefficiency at the collective level of many sport organisations is apparently mirrored in lower efficiency of investment at the individual level of Eastern athletic careers (Güllich & Emrich 2013). Nevertheless the search for sports talent became an important issue for numerous countries in their struggle for Olympic medals.

Table 22 Summary talent studies in sports '1970 – 1979'

Author	Year	Study	Method	Talent Aspect
GDR State Plan 14:25		Nationwide implemented talent system	Pyramid	Detection - Identification - Selection - Development
Wolkow	1974	Trainers opinion	Descriptive/comparative	Selection
Bar-Or	1975	Trainers opinion	Multiple regression	Identification - Selection
Gimbel	1976	Theoretical model (8-10 y training)	Deselected towards recreation	Identification - Development - Orientation
Jones & Watson	1977	Trainers opinion (observed skills)	Predictors / Performance	Identification
Geron	1978	Shift talent characteristics	Predictors / Performance	Identification - Development
Gabler & Ruoff	1979	Theoretical model stages athletic career	Predictors / Performance	Identification - Development

4.2 TIME PERIOD 1980 – 1989 (TALENT IN DIFFERENT DOMAINS)

One of the first attempts to detect talent in sport in the 1980s was implemented by Harre (1982). The model was based on the assumption that talent could only be trained. Therefore, the first step in Harre's model was to put as many children as possible through training programmes. Montpetit and Cazorla (1982) attempted to refine Gimbel’s earlier study (Gimbel, 1976) by accentuating the morphological variables. They suggested from their study of swimmers that the evolution of underlying performance factors, and thus performance itself, could be predicted. They indicated that mature early elite not always persists into elite adults. Moreover, the classic pyramid system entails the risk that talented individuals are wrongly oriented.

The most important talent model in the 1980s was developed by Bloom (1985) as it became the foundation for many of the current theories in talent development. Bloom based his model on interviews with talented individuals from different domains i.e. art, science and sports. The model consisting of three stages was based on common patterns from interviews. The three stages “Early years”, “Middle years” and “Later years” were later adopted by other authors (Régnier et al., 1993, Coté, 1999; Van Rossum, 2009) as the “Initiation phase”, “Development phase” and “Perfection phase”. In Bloom’s model it was stated which properties an athlete, parent and coach must possess to become an elite athlete.

Bompa (1985) suggested that children who found a sport through scientific selection progressed far more quickly than those who self selected naturally because they had qualities matched to the sport. He suggested that talent detection is beneficial for the individual, as they should achieve more quickly, have a higher chance of reaching international level and should feel more confident because they were chosen for their suitability for the task in question. How individuals find a domain to express their aptitudes or gifts is of central importance to those who value talent detection (Bompa, 1985). Natural selection was described as an individual taking part in a sport as a result of local influence, such as school tradition, parents' wishes or peers. Certainly Bompa (1985) suggested that gifted individuals would feel more confident if they were selected because of their gifts. This does not necessarily make them confident people, but it does suggest that they are trusting. When selected because of their gifts, athletes trust that the selection procedure accurately detected giftedness within them and subsequently believe in those gifts.

Matsudo et al., (1987) compared 6 levels from non-athletic to international basketball and volleyball elite players on different anthropometric and performance variables using percent differences and z-score values. The use of large cross-sectional norms on Brazilian girls and boys aged 7 to 18 years within a six level competition plan helps to assess development status and monitor change. Differences in physique and performance at various levels of competition compared to non-athletic prototypes may be used for talent selection and talent development (Matsudo et al., 1987).

Nationwide implemented Talent Systems

During the eighties, the world leading organization and structure of the GDR sports program implemented talent identification programs based on performance test batteries. The GDR performance system incorporated systematically all young children, while the western policy was to identify and support talented individuals after they became successful. The compulsory talent detection in the German primary schools caused an extraordinary influx of talented athletes in different sports and the selection of the better and the ruthless elimination of the weak were implemented during the different development phases. The primary schools were obliged to refer the 70,000 gifted athletes to one of the 2000 youth sports schools. The further development in 25 “Child and Youth Sport Schools” with 13,000 students and clubs was sport specific, with significant financial and material support for more than 6,000 trainers (compared to 120 in West Germany) (Güllich et al., 2013). Talent development necessitated full-time commitment and the search for specific sports disciplines with the opportunity to score at international competitions. In an attempt to be successful, several countries would copie these strategies in the next decades.

Table 23: Summary talent studies in sports ‘1980 – 1989’

Author	Year	Study	Method	Talent Aspect
Harre	1982	Genetic characteristics and social context	Reach as many children as possible	Detection - Identification - Selection - Development
Montpetit & Cazorla	1982	Predicition of performance	Trainers judgement & Motivation	Identification - Selection - Transfer
Bompa	1985	Scientific selection	Talentidentification in different sports	Detection - Identification - Selection - Development
Bloom	1985	Talented individuals from different domains	Interviews "Early-Middle-Later"	Identification - Development
Matsudo	1987	Z-score strategy	Predictors / Performance	Identification - Selection

4.3 TIME PERIOD 1980 – 1989 (SLIDING POPULATIONS)

A mixed longitudinal and cross-sectional talent model from Régnier et al. (1993) divided talented athletes into different age groups. The 'Sliding population approach' is a stepwise approach with specific test batteries for different age groups in order to predict whether athletes can or cannot reach the top level of the following age group (Figure 40).

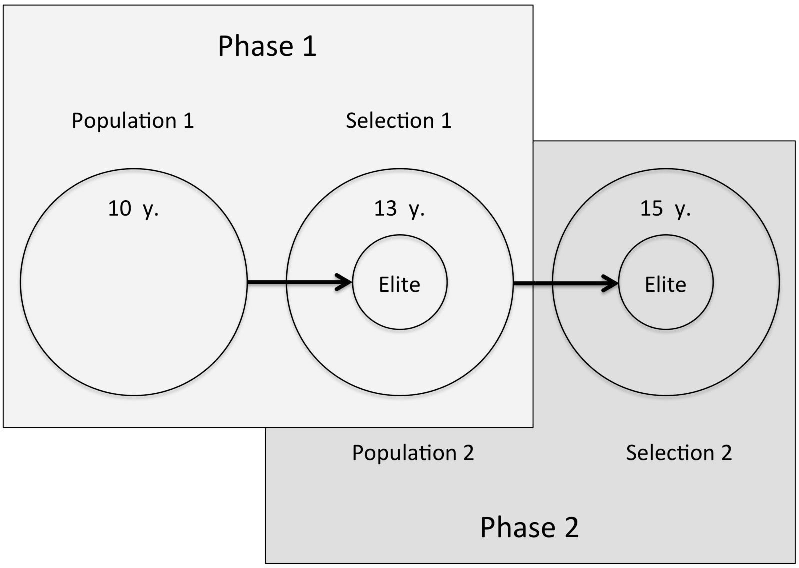


Figure 40: The sliding population approach (adapted by Régnier et al., 1993)

This approach has the advantage that there is room for athletes that missed a selection. The model seems appropriate in sport practice since the development of various talent characteristics shows different timing. The evaluation of gross motor talent characteristics is important in an initial population (6 to 9 year) physical talent characteristics becomes more important in a subsequent population (9 to 12 year) and in a further phase of athletic development the technical characteristics have an important impact on sports performances. The model of Régnier and colleagues thus utilizes different test batteries at different points in time to assess the most important characteristics related to the specific age groups.

In 1993 Csikszentmihalyi and colleagues reported on a four-year study of 208 talented US high school students. The study was arguably the most significant contribution to the understanding of talent since Bloom's (1985) work. Csikszentmihalyi et al.'s study was similar to Bloom's because they selected talented individuals across the domains of arts, sport, music, mathematics and science. Both authors also presupposed that talents could not develop without nurturing through a developmental process and favourable environmental factors. However, closer examination reveals how Csikszentmihalyi et al. (1993) contrasted Bloom's (1985) work. An important difference to recognise was how both studies used the word talent. While Bloom used the term to describe an unusually high level of demonstrated skill, Csikszentmihalyi et al. used it in reference to gifts and aptitudes as well as competencies and talents. Csikszentmihalyi et al.' s participants were nominated as gifted by teachers. In contrast Bloom's participants were selected for their outstanding achievements (talent). Consequently, Csikszentmihalyi et al.'s study focused upon what makes talented teenagers unique and what contributes towards them engaging or disengaging from developing their talents, while Bloom (1985) focused on how successful individuals had developed their talents. Consistent with this focus, Bloom's participants developed their gifts to a talented level, while Csikszentmihalyi et al.'s (1993) participants were all identified as gifted but had not yet reached the level of being talented.

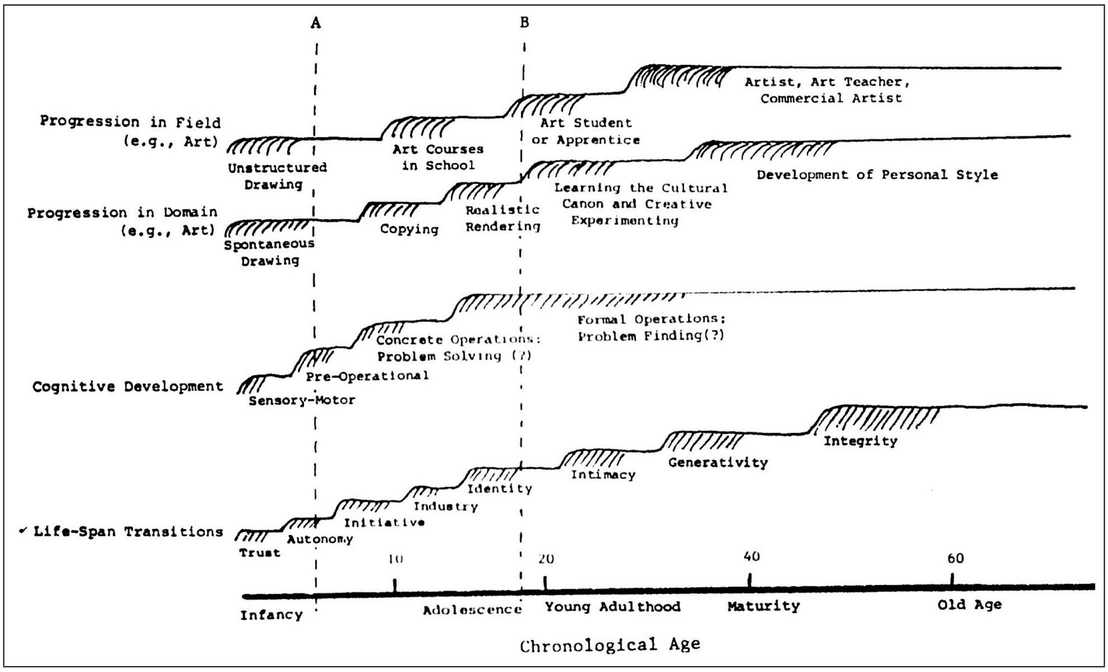


Figure 41: Differences in development of individual talent characteristics at time A and B, (Czikzentmihalyi, 1988)

Ericsson, Krampe and Tesch-Romer (1993) presented a theoretical framework to explain expert performance as the result of extensive engagement in relevant practices. The framework was formulated in light of the unsuccessful search for stable inheritable characteristics that could predict or account for the performances of talented individuals. As part of their theoretical framework, they proposed two important concepts. The first was the notion of deliberate practice and the second became known as the 10-year rule for the development of expertise. They contested that deliberate practice was more than just repetitive rehearsal with a "more of the same" undertone to it and described it as fully concentrating on a special activity to improve performance. The 10-year rule was based on studies in the development of expertise from a wide variety of disciplines i.e. chess, music, mathematics, sports including their own studies of violinists and pianists aided the formation of the 10-year rule. However, it should be noted that Ericsson et al. (1993) cited the work of Chase and Simon (1973) to eliminate the idea that the gifted individuals progress faster to an elite level. Crucially, however, Ericsson and colleagues (1993) presented no measures of variance in the results in their study. That is, no SD or ranges were provided, and as such, it is unclear whether the association between training and performance applies to every individual. It must be emphasised that individual variation within groups is of crucial significance. An individual who is able to achieve best expert levels can, according to this model, do so only if they engage in sufficient deliberate practice. Similarly, the theory predicts that an individual who fails to attain expert levels must fail because they have not accumulated the required training time. Any individual who violates either of these conditions, either by achieving best expertise with less time or by failing to achieve expert levels despite exceeding the training volume of peers, call into question the theory that posits that performance is the result of selective activation of DNA possessed by all individuals (Tucker and Collins, 2012).

Côté (1999) extended Bloom's earlier work with talented individuals through qualitative interviews with elite athletes from different sports i.e. gymnastics, rowing, basketball, netball, hockey and tennis. Similar to Bloom, The Developmental Model of Sport Participation (DMSP) contained three stages of development (Figure 42). Due to their experience with sport up to national level, it was felt that these performers and their families would be a rich source of qualitative information to illuminate the influence of the family in talent development. Across the families different in depth interviews of the performers, their parents and siblings were conducted. Although Bloom (1985) had also purposefully selected talented performers and interviewed their parents, Coté considered the influence of the whole family, interviewing siblings as well, which demonstrated the contribution made by other people in the development of an individual's talent. From his research, Coté theorised three stages of talent development as the sampling years, the specialising years and the investment years. The role of the parents was highlighted to create opportunities for sports participation with the emphasis on fun and experience in different sports during the “sampling years”.

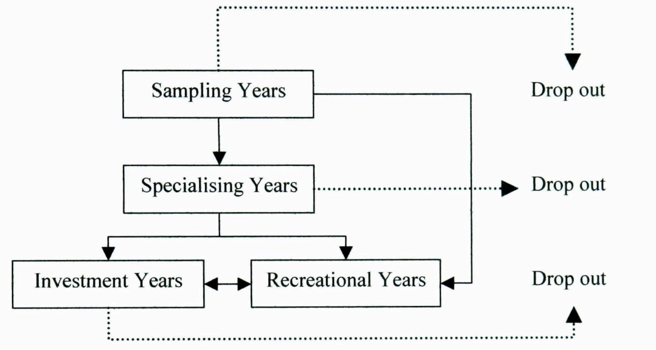


Figure 42: Stages of sports participation from early childhood to late adolescence (Coté, 1999)

The DMSP contains an important distinction between ‘deliberate play’ and ‘deliberate practice’. Ericsson, Krampe and Tesch-Römer (1993) concluded in their comprehensive review of the literature on skill acquisition and expert performance with the finding that the most effective learning occurs through participation, in what they called ’deliberate practice’. This form of practice requires effort, is not inherently enjoyable and is specifically designed to improve performance. Expert performance was the result of extensive deliberate practice (for at least 10 years). Côté (1999) introduced the term ‘deliberate play’ to describe a form of sporting activity that involves early developmental physical activities that are intrinsically motivating, provide immediate gratification and are specifically designed to maximise enjoyment. Deliberate play usually involves a modified version of standard rules, requires minimal equipment, flexible contexts and challenges, and allows children the freedom to experiment with different movements and tactics.

Nationwide implemented Talent Systems

This decade was also characterised by the rise of the Australian sports system. In 1989 the Australian Sports Commission decided that it would target sports in which Australia could do well internationally and seven sports were chosen. The budget for the program was $ 10 million, to be divided between basketball, canoeing, cycling, hockey, rowing, swimming and track and field. The additional funding was available to hire an international-level head coach for each sport, to establish a state-based Intensive Training Centre (ITC) and to make international competition more available for athletes in the above sports. By the early 1990s, targeted support was beginning to work well in 1994, when the Olympic Athlete Program commenced. The Australian Institute (AIS) developed the first successful talent detection programme in the western world called the 'Talent Search'. This programme was inspired by Dr. Hahn's successful detection of talent in rowing and led to the Australian rowers being fast tracked to the 1992 and 1996 Olympics (Tranckle, 2005). The combination of the establishment of more state or territory institutes/academies of sport, the increasing development and decentralisation of the AIS and the cooperation of the national sports organisations has contributed to an effective and efficient national elite sports program in Australia. The medal tally from the targeted sports increased from 12 in Seoul in 1988 to 22 in Barcelona in 1992 to 31 in Atlanta in 1996, reaching a total of 37 in Sydney in 2000 (Bloomfield, 2003).

Table 24: Summary talent studies in sports ‘1990 – 1999’

Author	Year	Study	Method	Talent Aspect
AIS (eTID)	1990	Talent Search	Australian Talent System	Detection - Identification - Selection - Development - Transfer - Orientation
Règnier et al.	1993	Sliding population approach	Mixed longitudinal - cross-sectional	Identification - Selection - Development
Ericsson et al.	1993	10.000 houres rule	Talent development	Identification - Development
Csikszentmihalyi et al.	1993	Engagement / Disengagement (gifted)	Interviews "Early-Middle-Later"	Identification - Development
Coté	1999	Development model of sport participation	Deliberate play - Deliberate practice	Identification - Selection - Development

4.4 TIME PERIOD 2000 – 2009 (GIFTEDNESS AND TALENT)

Abbott and Collins (2002) suggested that talent identification systems exclude many talented children and at the same time select individuals who will eventually fail to develop their talents. The influence of the maturity status and the influence of previous experience are factors that deserve more attention in this context. The possibility to compensate talent characteristics supported their objection against the effectiveness of unidimensional models, with a higher risk to select false positives and to de-select false negatives (Figure 43).

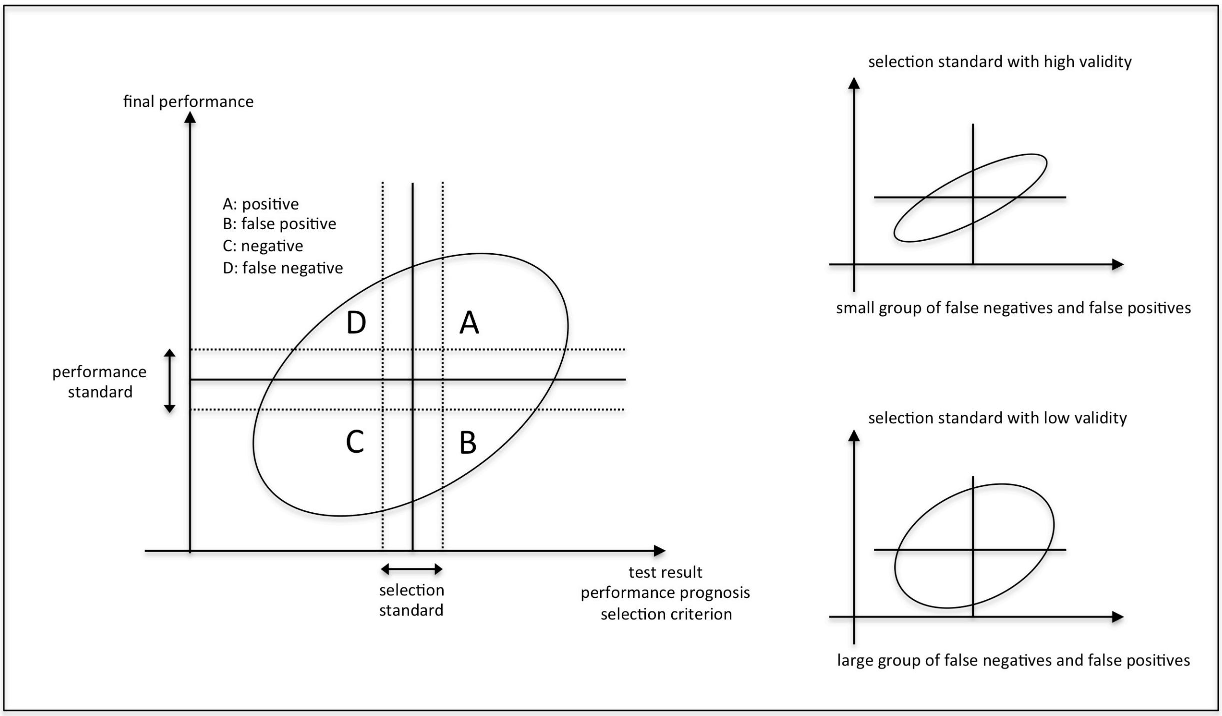


Figure 43: Risk of error in talent selection due to the uncertainty of performance prognosis (According to Baur 1988)

The model from Abbott and Collins (2004) combines different aspects of former theoretical concepts and makes a clear distinction between talent identification and talent development. The authors argue for the development and permanent control of all skills that can facilitate talent development. This is in contrast to the approach which emphasis talent identification as a predictor of talent development. The model from Abbott and Collins (2004) combines different aspects of former theoretical concepts. The talent identification shifts from determinants of potential to determinants of performance while the development of the athlete evolves from sampling over specializing and investment to maintenance stage. The psychological skills are the most prevalent discriminators between the elite performers (Figure 44). They also are important to facilitate the transitions between the different phases in this model. Diversified involvements in a number of sports during early stages of development have been presented as a possible alternative to early specialization. Considering the consequences of advocating the early specialization approach and research suggesting the effectiveness of early diversification, coaches and sport scientists should consider the early diversification approach as an alternative.

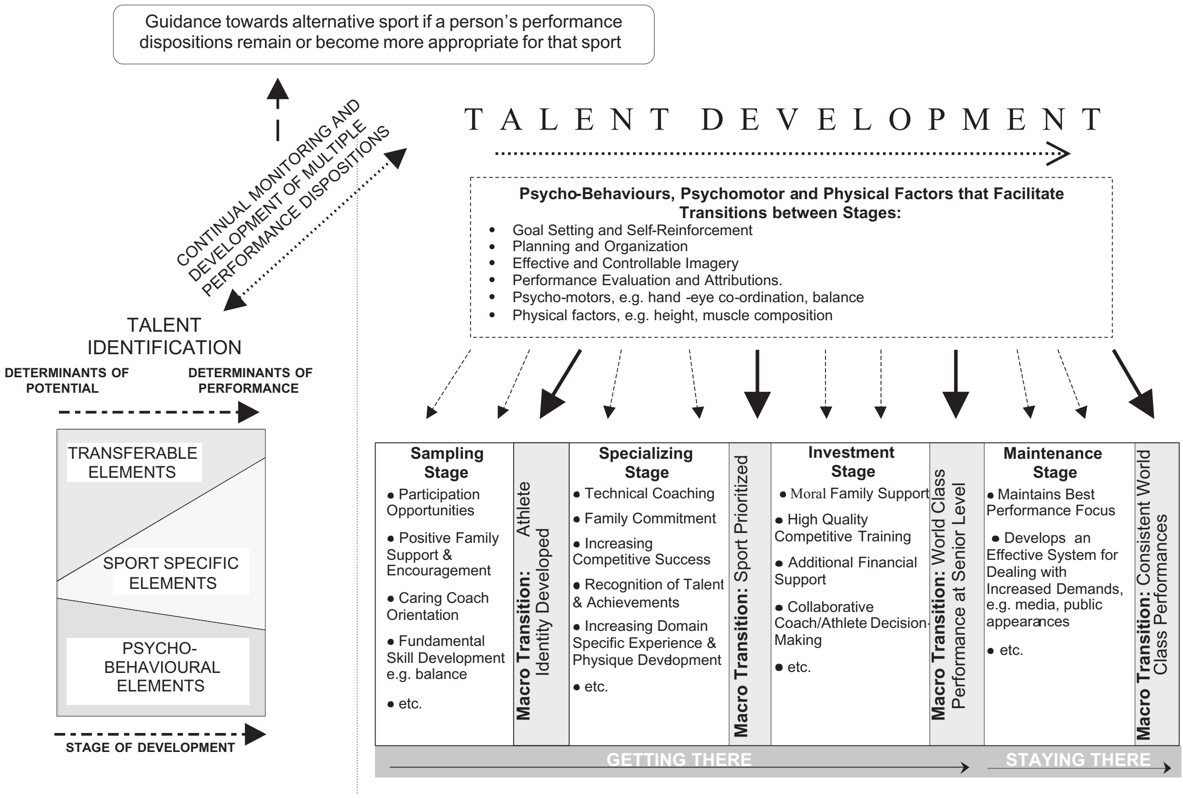


Figure 44: The multidimensional and dynamic concept of talent. (According to Abbott and Collins 2004)

Gagné (2004) made a clear distinction between giftedness and talent. The "Differentiated Model of Giftedness and Talent" (DMGT) describes how natural abilities can become systematically developed skills influenced by several factors. Talent can thus be developed by transforming gifts 'raw material' into talent 'ultimate achievement' through a process of learning, practice and training influenced by various intrapersonal and environemental factors 'catalysts' and chance. Intrapersonal catalists include physical characteristics, motivation, volition, self-management and personality. Environmental catalysts include friends and peers, social class, economical and geographical factors and the way in which the environment is structured to facilitate training improvement (Figure 45).

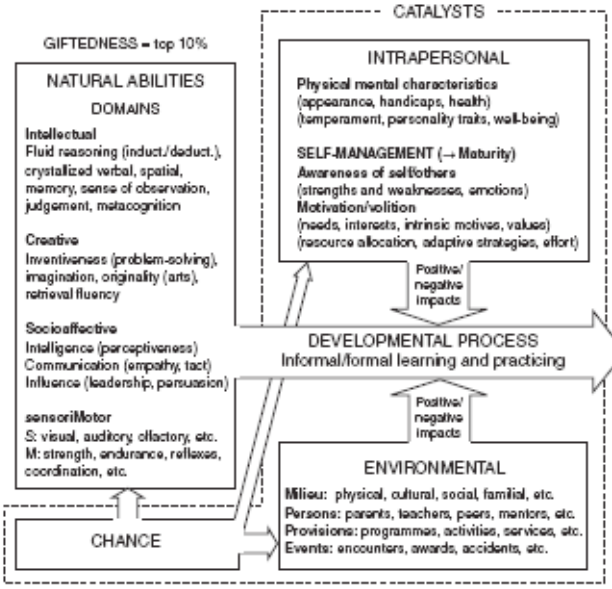


Figure 45: The Differentiated Model of Giftedness and Talent (Gagné, 2004)

According to Van Rossum and Gagné (2005) the normative concepts of giftedness and talent, can sort out the populations that differ from the norm. Within the DMGT these limits are set at the 90th percentile. The 10% best are further subdivided into the DMGT within the block giftedness: 1 in 100 are called moderately gifted, 1 in 1000 are highly gifted, 1 in 10,000 are exceptionally gifted and 1 in 100,000 are classified as extremely gifted. According to Gagné the choice to exactly draw the line is an instinctivly-determined separation standard, not based on scientific research.

Balyi & Hamilton 2004 indicate that ultimately, sustained success comes from training and performing well over the long-term rather than winning in the short-term (Long Term Ahletic Development, LTAD). Overemphasizing competition in the early phases of training will always cause shortcomings in athletic abilities later in an athlete’s career (Figure 46). Coaches worldwide currently design long and short-term athlete training models as well as competition and recovery programs based on their athletes’ chronological age. Yet, research has shown that chronological age is not a good indicator on which to base athlete development models for athletes between the ages of 10 to 16. There is a wide variation in the physical, cognitive and emotional development of athletes within this age group. Ideally, coaches would be able to determine the biological age of their athletes and use this information as the foundation for athlete development models. Balyi & Hamilton 2004 propose a practical solution designed by Mirwald et al., (2002), using the onset of Peak Height Velocity (PHV) as a reference point for the design of optimal individual programs with relation to “critical” or “sensitive” periods of trainability during the maturation process.

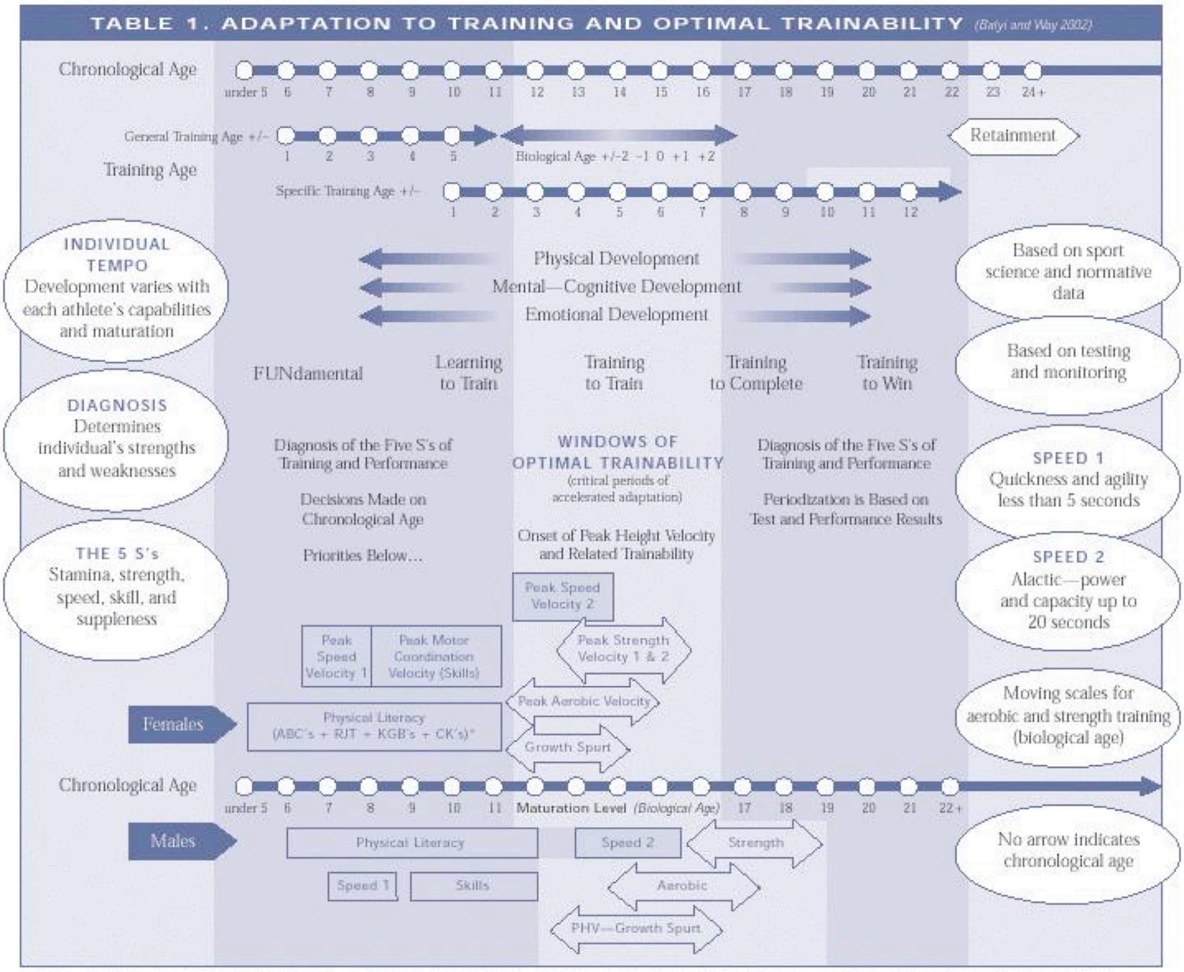


Figure 46: Adaptation to training and optimal trainability (Balyi and Hamilton 2004)

The model introduced by Bailey and Morley (2006) differentiates between potential and performance in school 'Physical Education'. Since individual development is the result of an interaction between inherited abilities and social and cultural learning, it is an error to assume correlations of ability and performance (Oyama, 2000). Therefore, from the point of view of talent development, current performance is a poor indicator of ability, since it is mediated through a host of other influences, such as training, support, parental investment and societal values.

Bailey and Morley (2006) distinguish between the expression of abilities and the progressive emergence of these abilities into certain formalised outcomes. These abilities are developed within certain domains that are (sometimes) refined, combined and elaborated into particular behaviours, such as sporting success. These abilities are: physical ability; inter-personal ability; intra-personal ability; cognitive ability and creative ability. Underlying this multidimensional framework is a claim that success in sport needs to be understood in terms of the emergence of a wide range of abilities rather than simply physical prowess, which has tended to dominate talent development practices.

In addition it does seem reasonable to mention that deliberate practice is a necessary condition of the realisation of talent. Of course, not all practices are equally valuable and mere quantity of practice is unlikely to result in expert performance; quality of practice is also required (Figure 47).

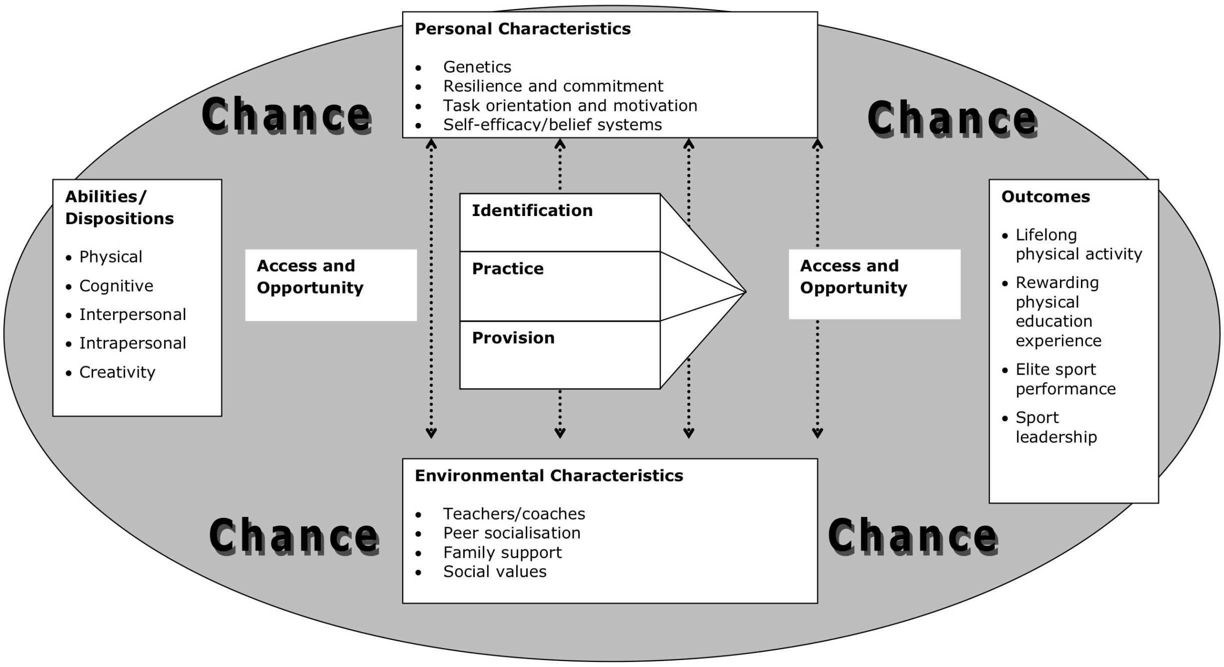


Figure 47: Multidimensional framework (Bailey and Morley, 2006)

Côté et al. (2007) advocated for a "deliberate play” approach in response to Ericsson’s “deliberate practice” approach (Ericsson et al., 1993; Ericsson and Charness, 1994). Ericsson’s early specialisation idea demanded deliberate practice i.e. repeatedly practice of specific skills in a controlled manner. In contradiction Coté’s approach in which pleasure is central leads to a smaller dropout, which was described by many authors as a result of the exercise unilateral and monotonous in "deliberate practice" (Wiersma, 2000; Wolstencroft, 2002; Baker, 2003; Côté et al., 2007). Moreover, these authors were also concerned whether children can handle such heavy training, both mentally and physically.

Early specialisation can have negative consequences for young athletes and lead to a reduction of general skills and general development Wiersma (2000), Wolstencroft (2002).

Coté and colleagues included recreation and early specialisation in the Developmental Model of Sport Participation (Coté et al., 2007). The authors introduced the "deliberate play 'approach in Developmental Model of Sport Participation (DMSP) to counter the ‘deliberate practice 'approach from Ericsson et al. (1993). The "deliberate play" that focuses on fun experience, allows an increasing intrinsic motivation (Molinero et al., 2006). Consequently, a smaller dropout is expected. The DMSP of Coté and colleagues (Figure 48) distinguish three phases.

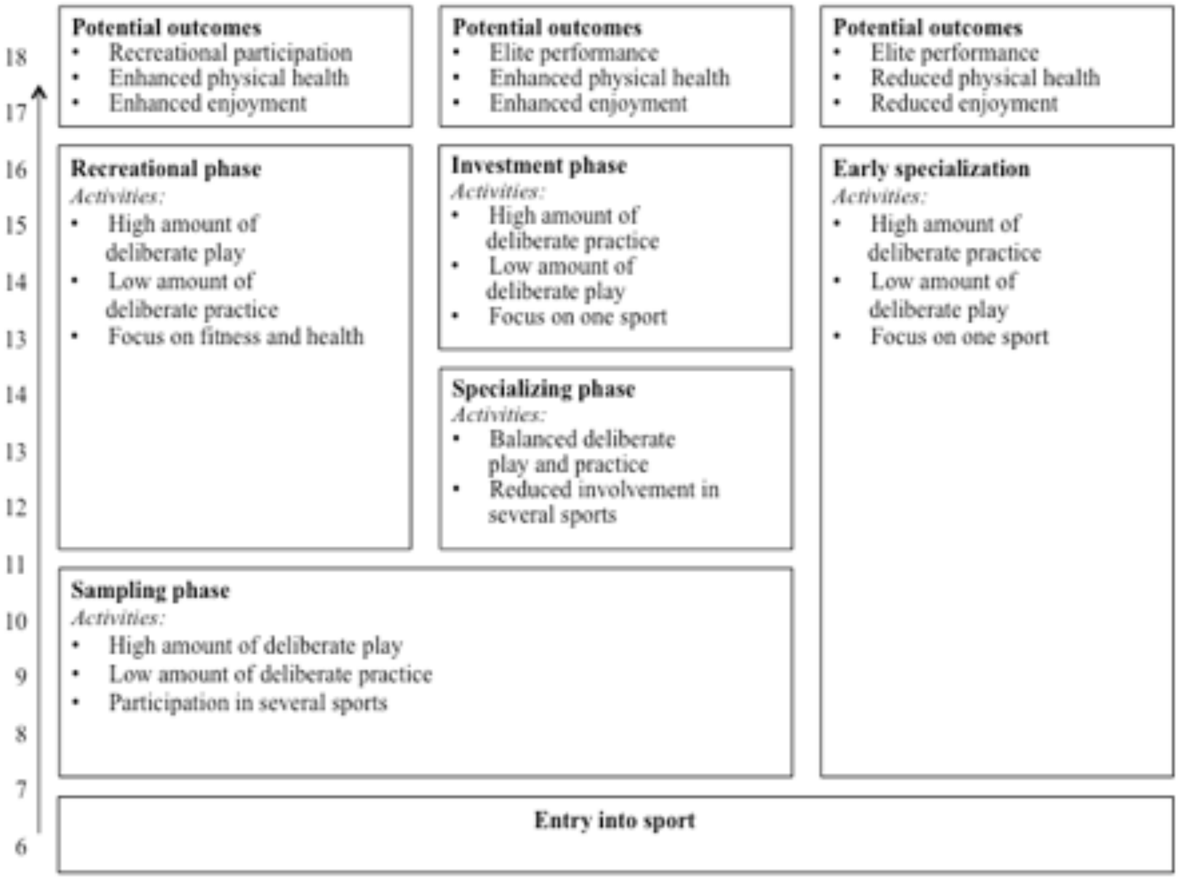


Figure 48: Development Model of Sport Participation (Coté et al., 2007)

Both fun experience of the young athletes and the versatile sport development are important during the sampling years. In this phase, young people develop intrinsic motivation towards sport and are encouraged to sampling more than one sport. The second phase is called the phase of the specialization of years, which takes place around the age of 12 to 14 years. This phase limits the young athlete to a pair of sports. The third stage is the phase of the investment years. During the investment phase, the athlete tries to make his way to the elite level in the chosen specialization. An elevated 'deliberate practice' and an increased focus of the athlete is required. The DMSP model also focuses on recreational athletes. This model therefore focuses on all athletes and does not exclude the less gifted athletes.

The “Münchner Hochbegabungsmodells” (Heller 2004) is based on talent characteristics (predictors) environmental factors and personality traits (moderators), which result in performance areas. The Munich Model of Giftedness by Heller and Perleth uses a multifactorial approach to explain giftedness and the development of it. The model is based on four interdependent multifactorial dimensions: talent factors (relatively independent), resulting performance areas, personality factors, and environmental factors; the latter two moderating the transition from talent (gifts) to performance. Consequently, Hohmann (2009) modified the Munich High Ability Test Battery with insights inspired by Gagné (2000) (Figure 49).

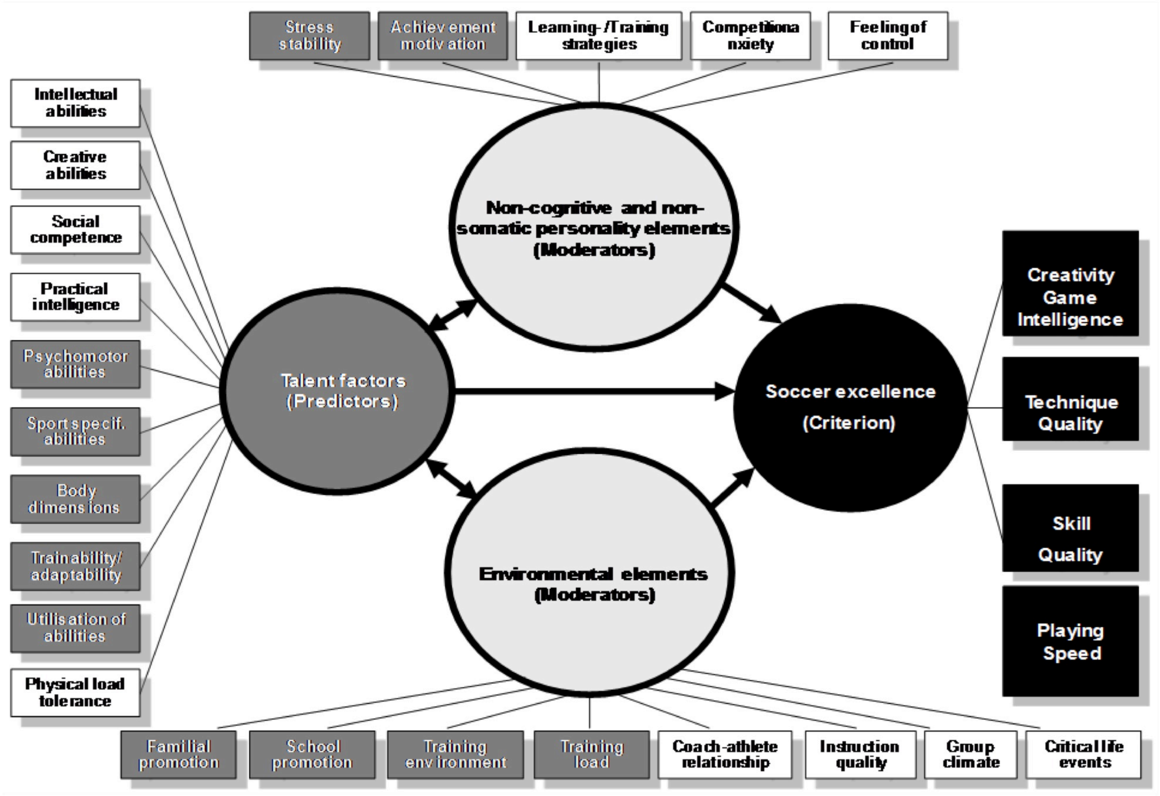


Figure 49: Munich High Ability Test Battery adapted according Gagné (Hohmann, 2009)

Bullock et al., 2009 aimed to transfer talent, rapidly develop, and qualify an Australian female athlete in the skeleton event at the 2006 Torino Winter Olympic Games and quantify the volume of skeleton-specific training and competition that would enable this to be achieved. All completed runs and simulated push starts were documented over a 14-month period. Using a deliberate programming model, these findings provide a guide to the minimum exposure required for a novice skeleton athlete to reach Olympic representative standard following intensified sport-specific training. The findings are discussed in the context of the deliberate practice theory and offer the term ‘‘deliberate programming’’ as an alternative way of incorporating all aspects of expert development.

Two projects with excessive budgets characterized the start of the new millennium. First, in China ‘Project 119’ was launched in 2002, the name of the program alluded to the number of medals that China wanted to achieve during the Olympic Games in their own country in 2008 (Jones, 2008), the government supported athletes in sports that traditionally yielded less medals in previous Olympics, with unlimited funds to achieve success in athletics, canoeing, rowing, sailing and swimming. Second, at the same time the UK Sport programs were launched in Britain in 2002 in preparation of the London Olympics in 2012. UK sport is an organization that stands between the combined athlete / sports federation and policy. The key tasks are to improve the climate of the sport by performance monitoring and evaluation of sport systems and structures. Talent identification is one of the five departments where talent identification; talent selection; talent transfer; talent confirmation and

World-class development succeed each other. Since 2007, major campaigns were launched to find athletes: Sporting Giants males (2007); Sporting Giants females (2008); Paralympics (2009). The success of this well organised system was shown in the medal standings at the London Olympics in 2012.

It is clear that the examples of the China and Great Britain are not possible for small countries, because of the excessive budgets for talent programs and the large size of the population from which these countries could recruit. The Netherlands and Canada implemented the Long Term Athlete Development (LTAD) model (Balyi, 2001 and 2007). The concept focuses on the general development of the athlete. However, different sport scientists discuss this model since there is a lack of scientific evidence for the “Windows of opportunity” (Ford et al., 2011; Tucker 2014). Inspired by the Australian Sport search programme “eTID” a similar interactive pilot programme “Sport Interactive” was used by Sportscotland. This interactive computer package matches young people to sports based on sporting preferences and on performance of a number of simple physical activity tasks (Wolstencroft 2002).

Table 25: Summary talent studies in sports ‘2000 – 2009’

Author	Year	Study	Method	Talent Aspect
China	2002	Project 119	Excessive budget different sports	Identification - Selection - Development
UK Sport	2002	UK Sport	Sporting giants, Paralympics, ... campaigns	Identification - Selection - Development - Transfer
Sport Scotland	2002	Talent System Scotland	Interactive	Detection - Identification - Selection - Development - Orientation
Abbott & Collins	2004	Multidemensional and dynamic concept	Talent Identification and Talent Development	Identification - Development
Baliy & Hamilton	2004	LTAD (practice)	Optimal Trainability	Identification - Development
Gagné	2004	DMGT (theory)	Giftedness and Talent	Identification - Development
Heller	2004	MHBT	Development of Giftedness	Identification - Development
Bailey & Morley	2006	Potential & Performance in school PE	Individual development	Identification - Development
Coté	2007	DMSP	Deliberate Play / Training	Identification - Development
Bullock et al	2009	Rapidly develop talent (14 months	Deliberate Programming	Transfer - Development
Hohmann	2009	Adapted Munich Model	High Ability Test Battery	Detection - Identification - Selection - Development

4.5 TIME PERIOD 2010 – 2019 (DEVELOPMENT PATHWAYS)

Gulbin et al. (2010) evaluated the theory and surveyed a large pool of high performance athletes with established sports talent competencies (n=673), which included 51 Olympians, to look back at their experiences of their athletic development and to provide additional insights to refine talent development pathways for the next generation of athletes. The aim was to capture and chronicle a more plausible and generalisable account of talent development by applying Gagné’s framework (Gagné 2009) to the development, validation and administration of a customised National Athlete Development Survey (NADS). The data provided a valuable and realistic insight into the development of sporting talent, which incorporates a diverse range of sports (34 in total). The Athlete Development Triangle featuring an inherent flexibility within its design to account for progression, digression and direct crossover (i.e., junior to senior) in competition levels made it possible to establish a more meaningful and realistic map of the journey to an elite status than has been provided in the literature to date (Figure 50).

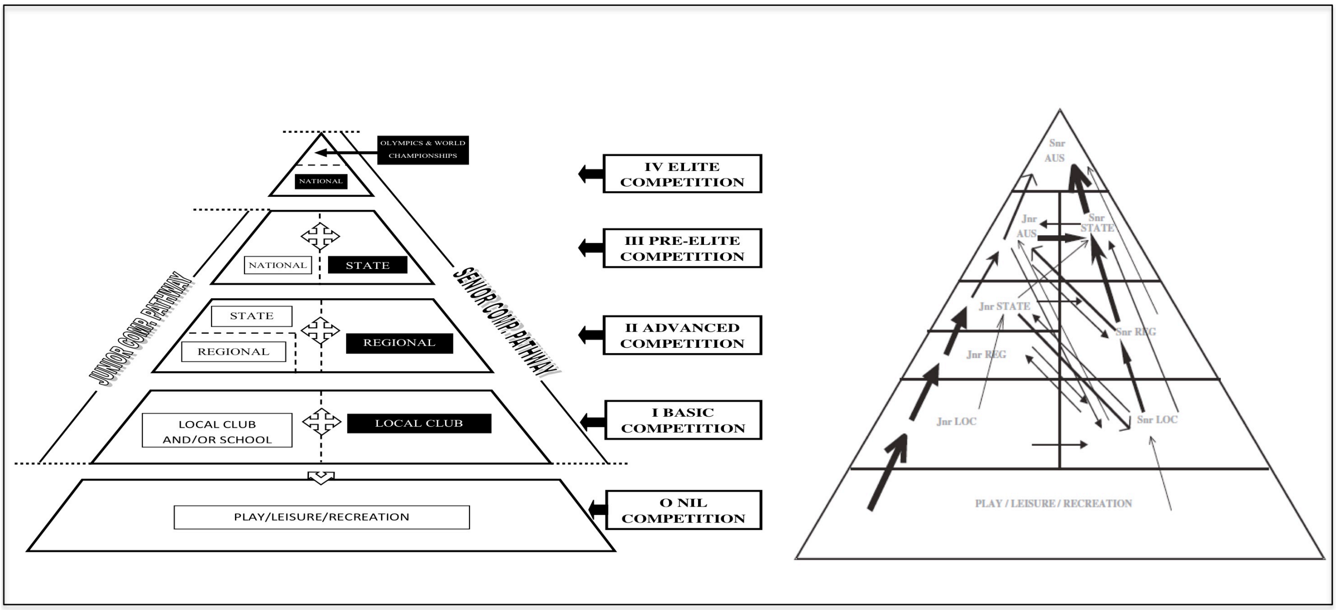


Figure 50: Transitions in the Athlete Development Triangle (Gulbin et al., 2010)

FTEM (Foundations, Talent, Elite, Mastery), a new practitioner derived sport development framework presented by Gulbin and colleagues (2014), combines the insights and experiences of a world leading high performance sports agency with the theoretical perspectives offered within the sport and athlete development literature. FTEM is unique in comparison with alternative models and frameworks, because it: a) integrates general and specialised phases of development for participants within the active lifestyle, sport participation and sport excellence pathways; b) typically doubles the number of developmental phases (n = 10) in order to better understand athlete transition; c) avoids chronological and training prescriptions; d) more optimally establishes a continuum between participation and elite; e) and allows full inclusion of many developmental support drivers at the sport and system levels. The FTEM framework offers a viable and more flexible alternative for those sporting stakeholders interested in managing, optimising, and researching sport and athlete development pathways.

Success can be measured by the amount of athletes competing and the number of medals won at international competitions. Talent prediction becomes more and more important. The pressure to win medals augments for sports administrations all over the world. Unfortunately, there is not always reflected in advance about the selection and the impact of psychological and social problems of athletes who do not achieve their objectives. Therefore, a more accurate performance prediction becomes more important and in the most recent studies, predictive statistical methods were applied. Hohmann (2009) highlighted the importance of linear and non-linear techniques and accentuated that discriminant analyses and artificial neural networks become more important in the decision to select high potential athletes. A recent study by Allen et al. (2014) compared the predictive accuracy of four methods for early selection of Australia’s 2012 Olympic-qualifying swimmers using a retrospective simulation approach. This study shows that non-linear statistical methods can also be applied to predict performance and hence become the standard for talent search.

Nationwide implemented Talent Systems

Many countries started to copy the successful talent transfer strategy to improve their chances in addition to a development strategy over a shorter time to get the best possible return. The nationwide-implemented talent system mostly targets the next Olympic games and in many cases another four years later.

UK Sport is currently the shining example and has a lot of resources in comparison with other countries. UK Sport generates most of the funds and is considered a bank that stands between the government and the sports federations. For Rio 2016, 60% of the funds are used, the remaining 40% will be spent on projects for Tokyo 2020. Compete to stage (2011); Fighting Taekwondo Champ (2012); Campaigns through YouTube and Twitter (2014) were the latest campaigns to promote elite sports. Having a clear vision and starting with the end in mind are important recommendations handed by Stuart Laing at the talent identification conference in Qatar (2014). Both advices need sustainable high performance systems, where each layer operates in function of the following layer to find the right athlete in the right environment (Laing 2014).

During the same conference in Qatar (2014), two sport scientists noticed that the Australian system has known better days with more funds. AIS impose targets and supports different projects in different regions. The regions now adopt the National TID model of the 2000s'. Sport is considered as a product with managers who impose objectives to the performers. Tight deadlines and high standards are the norm. First the project 'Prospecting for gold' in Queensland targets two or three participants for the Olympic Games in Rio 2016, the quest for talent includes identifying and a fast development course to become a World Class Athlete in 20 months. (Mewing, 2014). Secondly, the limited funds and some Non-Olympic sports being more important are difficulties to be overcome, especially in a vast area with a relatively small population. The 'SASI talent search' (Eastwood, 2014) challenges the demographic problems. The system consists of three phases. The first phase is the talent detection in schools. The second phase is the advanced testing combined with sport specific tests. The third phase is the talent development phase. The campaign 'Backwards to London' supports the 'Talent Developing Pathways' supported by the talent identification systems of different sports federations to optimise talent inflow.

Douglas (2014) presented a talent system for Qatar, with the ambition to screen every boy in Qatar to lead high potentials to Aspire Academy. The system contains the same three phases of the former Australian campaign (bronze, silver and gold). The "Bronze" phase is a large-scale screening in 47 schools (3000 boys of 11 years). In this detection phase the aim is to select high potentials while avoiding to not de-select children.

The test battery includes generic measurements i.e. stature, weight, BMI, armspan, APHV, sprint 40m, endurance shuttle run, vertical jump, medecinbal throw (2kg). During the “Silver” phase 150 to 200 boys are invited to perform the same tests with the intention to validate the results of the first phase. In addition, coaches from different sports observe the selected boys. This is the final assessment or “Gold” phase for 60 to 80 boys who are invited to participate at the ultimate bootcamp. Sport specific assessments and motor coordination will lead to 30 newcomers in Aspire Academy. To become succesful, the aim is to consider all PE teachers as partners in this project. The evaluation of the boys in their own schools will lead to the detection of more high potentials.

Finally the Japanese model (Kinugasa, 2014) offers new dimensions to existing systems. The target is Tokyo 2020 and therefore short-term actions are combined with long-term projects. The system includes talent detection; talent identification and talent transfer resulting in 700 selected athletes for 12 regional centers. Three different types of talent academies were introduced first the classic talent academy with preliminary screenings and selections in a particular sport. Secondly specific Talent Transfer Centres try to transform outstanding athletes into new sports that suit their abilities. Third, the new Multi-Sport Centres develop high potentials (12-14 y) by means of sports clusters. This high level generic development based on clustered talent characteristics leads towards a future sports specialisation.

Table 26: Summary talent studies in sports ‘2010 – 2015’

Author	Year	Study	Method	Talent Aspect
Gulbin	2010	NADS	Retrospective study Olympians	Identification - Selection - Development
Douglas	2014	Talent System Qatar	Bronze - Silver - Gold (system)	Detection - Identification - Selection - Development - Orientation
Eastwood	2014	SASI 'Talent Search'	Chalenging demographic problems	Detection - Identification - Selection - Development
Gulbin	2014	FTEM	Sport & athlete development pathways	Identification - Selection - Development - Transfer
Kinugasa	2014	Targeting Tokyo 2020	Talent - Transfer - Multi sport academies	Detection - Identification - Selection - Development - Orientation - Transfer
Laing	2014	UK Sport	different campaigns (fighting champs...)	Identification - Selection - Development - Transfer
Mewing	2014	Prospecting for gold	Fast development (20 months)	Transfer - Development

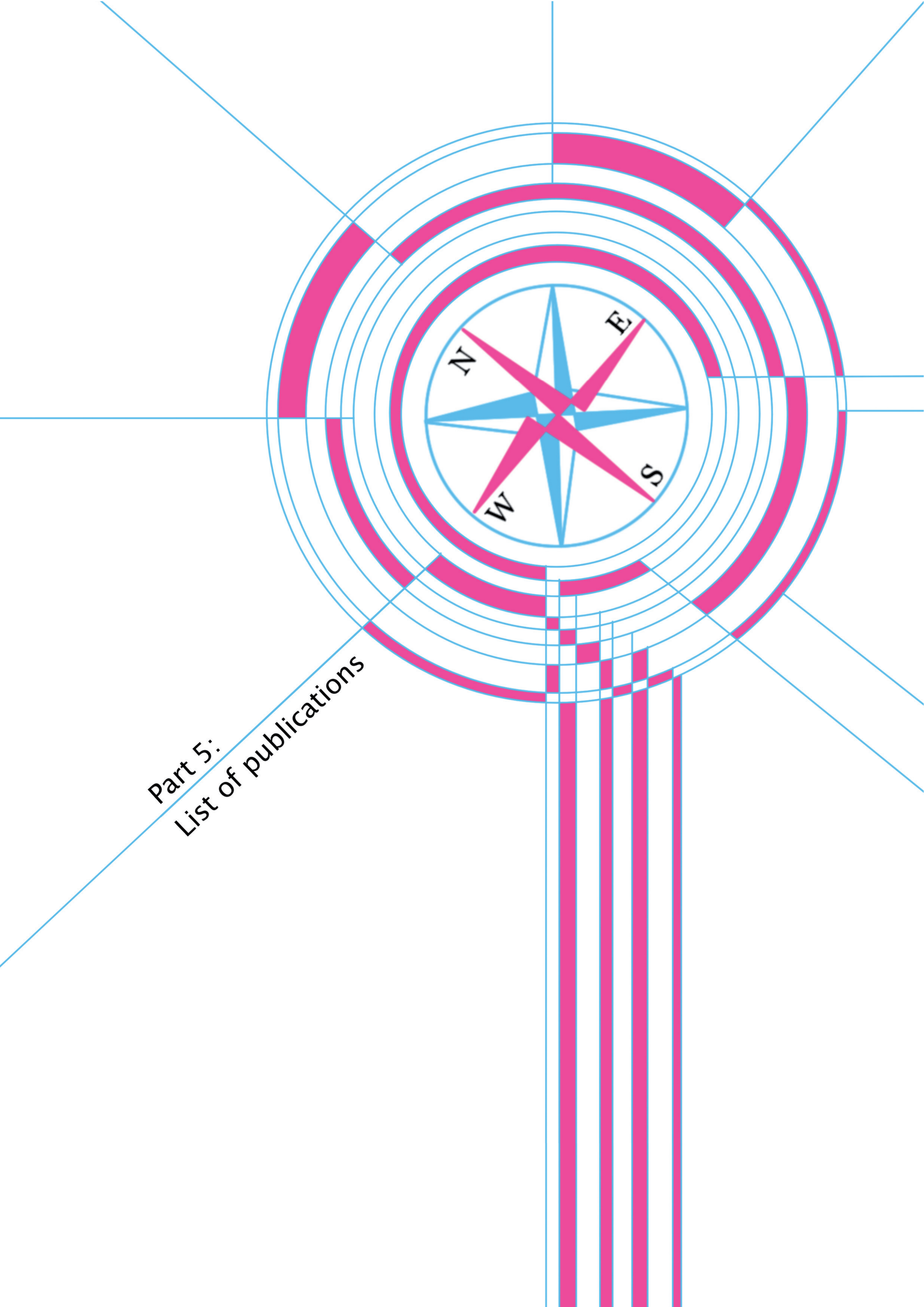
References

1. Abbott A, Collins D (2002). A theoretical and empirical analysis of a 'state of the art' talent identification model. *High Ability Studies 2002*; 13 (2): 157-78.
2. Abbott A, Collins D (2004). Eliminating the dichotomy between theory and practice in talent identification and development: Considering the role of psychology. *Journal of Sports Sciences*, 22, 395–408.
3. Allen, S. V., Vandenbogaerde, T. J., & Hopkins, W. G. (2014). Career performance trajectories of Olympic swimmers: Benchmarks for talent development. European journal of sport science, 14(7), 643-651.
4. Baker J, Côté J & Abernethy B (2003). Sport-specific practice and the development of expert decision-making in team ball sports. *Journal of Applied Sport Psychology, 15*(1), 12-25.
5. Balyi I (2001). *Sport System Building and Long-term Athlete Development in British Columbia*. Sports Med BC, Canada.
6. Balyi I, Hamilton A (2004). Long-term athlete development: Trainability in childhood and adolescence. *Olympic Coach*, *16*(1), 4-9.
7. Balyi I (2007). *Introduction to Long Term Athlete Development, in Talent centraal, NOC-NSF*, Editor. 2007, NOC-NSF: Papendal (NL).
8. Bailey R, Morley D (2006). Towards a model of talent development in physical education. *Sport, Education and Society*, *11*(3), 211-230.
9. Bar-Or O (1975). Predicting athletic performance, *Physician and sports medicine* 3 (2): 81-85.
10. Baur, J. (1988). Talentsuche und talentforderung im Sport 1, Leistungssport 18 (2): 5 - 10
11. Bloom BS (1985). Developing talent in young people. New York: Ballantine, 1985.
12. Bloomfield J (2003). Australia's sporting success: The inside story. UNSW Press.
13. Bompa T (1985) Talent Identification, Science periodical on research and technology in sport (February), Ottawa, Coaching Association of Canada.
14. Bullock N, Gulbin JP, Martin DT, Ross A, Holland T & Marino F (2009). Talent identification and deliberate programming in skeleton: Ice novice to Winter Olympian in 14 months. Journal of sports sciences, 27(4), 397-404.
15. Chase WG & Simon HA (1973). Perception in chess. Cognitive psychology, *4*(1), 55-81.
16. Côté J (1999). The influence of family in the development of talent in sport. *Sport Psychologist*, 13 (4), 395-417.
17. Côté J, & Fraser-Thomas J (2007). *The health and developmental benefits of youth sport participation*. Toronto: Pearson.
18. Csikszentmihalyi M, Rathunde K, Whalen S (1993). *Talented teenagers: The roots of success and failure*. New York: Cambridge University Press.
19. Douglas (2014). *Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014 "Sifting the sands – Talent identification at Aspire Academy*. Qatar."
20. Durand-Bush N & Salmela JH (2001). *The development of talent sport*. In : Singer RN., Hausenblas HA, Janelle CM, editors, Handbook of sport psychology, 2nd ed. New York: Wiley, 269-289.
21. Eastwood A (2014). Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014 "Talent Identification in South Australia. Challenges, interventions and successes"
22. Ericsson KA, Krampe RT & Teschromer C. (1993). The role of deliberate practice in the aquisition of expert performance. *Psychological Review, 100*(3), 363-406.
23. Ericsson KA, Charness N (1994). Expert performance: Its structure and acquisition. *American psychologist*, 49, 725-747.
24. Ford P, De Ste Croix M, Lloyd R, Meyers R, Moosavi M, Olive J, Tiill K & Williams C (2011). The Long-Term Athlete Development model: Physiological evidence and application, *Journal of Sports Sciences*, 29:4, 389-402.
25. Gabler H, Ruoff BA (1979). Zum problem der Talentbestimmung im Sport, *Sportwissenschaft* 9 (2) : 164-180.
26. Gagné F (1985). Giftedness and Talent: Re-examining a Re-examination ofthe Definitions. *Gifted Childs quarterly,* 29, 103-112.
27. Gagné F (2000). Understanding the complex choreography of talent development through DMGT-based analysis. *International handbook of giftedness and talent*, 2, 67-79.
28. Gagné F (2004). Transforming gifts into talents: the DMGT as a developmental theory. *High Ability Studies*, 15(2): p. 119-147
29. Gagné F (2009). Talent development as seen through the differentiated model of giftedness and talent. *The Routledge international companion to gifted education*, 32-41.

30. Geron E (1978). Psychological assessment of sport giftedness, in Simri U (ed.), *Proceedings of the international symposium on psychological assessment in sport*, Nataya : Wingate Institute, 216-231.
31. Gimbel B (1976). Possibilities and problems in sport talent detection and research [in German]. *Leistungssport* , 6: 159-67.
32. Güllich A & Emrich E (2013). Investment patterns in the careers of elite athletes in East and West Germany. *European Journal for Sport and Society*, *10*(3), 191-214.
33. Gulbin J, Oldenziel K, Weissensteiner J & Gagné F (2010). *A look through the rear view mirror: Developmental experiences and insights of high performance athletes*.
34. Gulbin JP, Croser MJ, Morley EJ & Weissensteiner JR (2014). A closer look at the FTEM framework. Response to "More of the same? Comment on 'An integrated framework for the optimisation of sport and athlete development: A practitioner approach'". *Journal of sports sciences*, *32*(8), 796-800.
35. Güllich A & Emrich E (2013). Investment patterns in the careers of elite athletes in East and West Germany. *European Journal for Sport and Society*, *10*(3), 191-214.
36. Harre D (1982). *Trainingslehre*. Berlin: Sportverlag.
37. Heller K (2004). Identification of Gifted and Talented Students, *Psychology science*, Volume 46, (3), p 302-323.
38. Hohmann A (2009*). Entwicklung Sportlicher Talente an Sportbetonten Schulen, Shwimmen-Leichtathletik-Handball*, Michael Imhof Verlag Gmbh&Co.KG, Petersberg.
39. Hungermann J. Viele ehemalige DDR-Leistungssportler können kaum noch stehen. (2006). [Cited 2006 22 november] Available from: http://www.welt.de/sport/article96480.
40. Jones G (2008). China's olympic plan to topple America [cited 2008 1 august] Available from: http://www.thefirstpost.co.uk/45023,news-politics, chinas-119 olympic-dreams.
41. Jones JG, Watson GG (1977). Psychological factors in the prediction of athletic performance, in Simri U (ed.), *Proceedings of the international symposium on psychological assessment in sport*, Nataya: Wingate Institute, 89-102.
42. Kinugasa T (2014). Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014. "Targeting Tokyo 2020 and beyond/ The Japanese TID model".
43. Laing S (2014). Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014. 3 To the London Olympics and beyond – talent identification practices in the UK"
44. Matsudo VKR, Rivet RE, Pereira MHN (1987). Standard score assessment on physique and performance of Brazilian athletes in a six tiered competitive sports model, *Journal of Sports Sciences*, 5, pp 49-53.
45. Mewing M (2014). Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014. "*Prospecting for Gold – a novel talent identification and development approach at the Queensland Academy for Sport*"
46. Mirwald, R. L., Baxter-Jones, A. D., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. Medicine and science in sports and exercise, 34(4), 689-694.
47. Molinero, O., Salguero, A., Tuero, C., et al., (2006). Dropout from youth sports: relationship to gender, type of sport and level of competition. Journal of Sport Behavior, 29, 255-270.
48. Montpetit R, Cazorla L (1982). La detection du talent en natation, *Revue de l'Entraineur* 5 : 26- 37.
49. Oyama S, Taylor P, Fogel A, Lickliter R, Sterelny K, Smith KC & van der Weele C (2000). *The ontogeny of information: Developmental systems and evolution*. Duke University Press.
50. Régnier G, Salmela J and Russell SJ (1993). Talent detection and development in sport. In Singer, R.N.; Milledge, M. en Tennant, L.K. *Handbook of research on sport psychology*, 290-313. New York: Macmillan Publishing company.
51. Tranckle (2005). *Exploring how gifts are discovered and why talents develop in sport*. Brunel University, Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine*, bjsports-2011.
52. Tucker, R., & Collins, M. (2012). What makes champions? A review of the relative contribution of genes and training to sporting success. *British Journal of Sports Medicine*, bjsports-2011.
53. Tucker R (2014) Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014. "The talent equilibrium: Finding balance between scientific prudence and strategic prerogatives"

54. Van Rossum JH and Gagné F (2005). Talent development in sports, in: *The handbook of Secundary Gifted Children*, F.A. Dixon and S.M. Moon, Editors, Waco: Prufrock Press. p. 281- 316.
55. Van Rossum JH. (2009). Giftedness and Talent in Sport. In Shavinina, L.V. *International Handbook of Giftedness*, 751-791. Dordrecht: Springer Netherlands.
56. Wiersma LD (2000). Risks and benefits of youth sport specialization: Perspectives and recommendations. *Pediatric Exercise Science, 12*(1), 13-22.
57. Wolkow WM (1974). Aktuelle Biologische Frage der sportlichen Auslese, *Leistungssport* 4 (6): 469-472.
58. Wolstencroft E (2002). Talent Identification and Development: An Academic Review. Edinburgh: Sportscotland.

Part 5:
List of publications



A1

1. Mireille Mostaert, Frederik Deconinck, **Johan Pion**, Matthieu Lenoir. Anthropometry, physical fitness and coordination of young figure skaters of different levels. (2015) International Journal of Sports Medicine, Submitted August 5th 2015
2. Jan Stautemas*, Veerle Segers*, **Johan Pion**, Jan Boone, Matthieu Lenoir, Jan G. Bourgois. Predictive models for position specific performance profiles in elite basketball. (2015) Journal of Science and Medicine in Sport, Submitted April 29th 2015
3. **Johan Pion*,** Andreas Hohmann*, Tianbiao Liu, Matthieu Lenoir, Veerle Segers. Predictive models reduce talent development costs in female gymnastics. (2015) Journal of Sports Sciences, Submitted March 12th 2015
4. Dieter Deprez D, Martin Buchheit, Job Fransen, **Johan Pion**, Matthieu Lenoir, Renaat M Philippaerts, Roel Vaeyens. A longitudinal study investigating the stability of anthropometry and soccer-specific endurance in puberal high-level youth soccer players. (2015) Journal of Sports Sciences and Medicine, 8; 14(2): 418-426
5. ***Johan Pion*,*** *Matthieu Lenoir*, Barbara Vandorpe and Veerle Segers.* Talent in female gymnastics: a survival analysis based upon performance characteristics. (2015) International Journal of Sports Medicine 36: 935-940, DOI/10.1055/s-0035-1548887
6. Katrijn Opstoel*, **Johan Pion*,** Marije Elferink-Gemser, Esther Hartman, Bas Willemse, Renaat Philippaerts, Chris Visscher, Matthieu Lenoir. Anthropometric, Physical fitness and motor coordinative characteristics of 9 to 11 year old children participating in a wide range of sports. (2015) PlosOne, Published May 15, 2015, DOI: 10.1371/journal.pone.0126282
7. **Johan Pion*,** Job Fransen*, Dieter Deprez, Veerle Segers, Roel Vaeyens, Renaat Philippaerts, Matthieu Lenoir. Stature and jumping height are required in female volleyball, but motor coordination is a key factor for future elite success. (2015) Journal of Strength and Conditioning Research, 29(6), p. 1480 - 1485
8. **Johan Pion**, Veerle Segers, Job Fransen, Gijs Debuyck, Dieter Deprez, Leen Haerens, Roel Vaeyens, Renaat Philippaerts, Matthieu Lenoir. Generic anthropometric and performance characteristics among elite adolescent boys in nine different sports. (2015). European Journal of Sport Science, 15(5), p 357-366
9. **Johan Pion***, Job Fransen**,** Matthieu Lenoir, Veerle Segers. The value of non-sport-specific characteristics for talent orientation in young male judo, karate and taekwondo athletes. (2014) Archives of Budo (10), p. 147-152
10. Dieter Deprez, Aaron James Coutts, Matthieu Lenoir, Job Fransen, **Johan Pion**, Renaat Philippaerts, Roel Vaeyens. Reliability and validity of the Yo-Yo intermittent recovery test level 1 in young soccer players. (2014) Journal of Sport Sciences 32(10), p.903-910.
11. Job Fransen, Dieter Deprez, **Johan Pion**, Roel Vaeyens, Matthieu Lenoir and Renaat Philippaerts. Changes in physical fitness and sports participation among children with different levels of motor competence: a two-year longitudinal study. Pediatric Exercise Science. (2014) 26 (1), p. 11-21

12. Stijn Matthys, Roel Vaeyens, Job Fransen, Dieter Deprez, **Johan Pion**, Joric Vandendriessche, Barbara Vandorpe, Matthieu Lenoir and Renaat Philippaerts. A longitudinal study of multidimensional performance characteristics related to physical capacities in youth handball. (2013) Journal of Sports Sciences 31(3). P.325-334

13. Barbara Vandorpe, Joric Vandendriessche, Roel Vaeyens, **Johan Pion**, Stijn Matthys, Johan Lefevre, Renaat Philippaerts and Matthieu Lenoir. Relationship between sports participation and the level of motor coordination in childhood: a longitudinal approach. (2012) Journal of Science and Medicine in Sport. 15(3). p. 220-225

14. Barbara Vandorpe, Joric Vandendriessche, Roel Vaeyens, **Johan Pion**, Johan Lefevre, Renaat Philippaerts and Matthieu Lenoir. The value of a non-sport-specific motor test battery in predicting performance in young female gymnasts. (2012) Journal of Sport Sciences 30(5). P497-505

15. **Job Fransen*, Johan Pion***, Joric Vandendriessche, Barbara Vandorpe, Roel Vaeyens, Matthieu Lenoir and Renaat Philippaerts. Differences in physical fitness and gross motor coordination in boys aged 6-12 years specializing in one versus sampling more than one sport. (2012) Journal of Sport Sciences 30(4). P 379-386

16. Stijn Matthys, Roel Vaeyens, Joric Vandendriessche, Barbara Vandorpe, **Johan Pion**, Aaron CouttsMatthieu Lenoir and Renaat Philippaerts. A multidisciplinary identification model for youth handball. (2011) European Journal of Sport Science 11(5). p. 355-363

17. Barbara Vandorpe, Joric Vandendriessche, Roel Vaeyens, **Johan Pion**, Johan Lefevre, Renaat Philippaerts and Matthieu Lenoir. Factors discriminating gymnasts by competitive level. (2012) International Journal of Sports Medicine 32(8). P591-597

18. Barbara Vandorpe, Joric Vandendriessche, Johan Lefèvre, **Johan Pion**, Roel Vaeyens, Stijn Matthys, Renaat Philippaerts and Matthieu Lenoir. The KorperkoordinationsTest fur Kinder: reference values and suitability for 6-12-year-old children in Flanders. (2011) Scandinavian Journal of Medicine and Science in Sports. 21(3), p. 378-388

19. Eva D'Hondt, Benedicte Deforche, Roel Vaeyens, Barbara vandorpe, Joric Vandendriessche, **Johan Pion**, Renaat Philippaerts, Ilse De Bourdeaudhuij and Matthieu Lenoir. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: a cross-sectional study. (2011) International Journal of Pediatric Obesity, 6 (2-2), p. e556-e564.

A3

* **Pion J,** Segers V, Lenoir M. Het Vlaams Sportkompas: een generieke testbatterij voor talentdetectie, -identificatie en –oriëntatie, oktober 2014, Bloso – VTS redactioneel

* Fransen J, **Pion J,** Lenoir M. Een grote gestalte en spronghoogte zijn belangrijke attributen voor vrouwelijke volleybalspeelsters, maar coördinatie is een échte sleutel tot success, januari 2014, Bloso – VTS redactioneel

* **Pion J,** Lenoir M. Detectie is de opstap naar een succesvolle talentontwikkeling in Judo

2014 JudoContact p. 16-16

* **Pion J**, De Geyter J, Lenoir M. Talent identificeren en selecteren in Judo (deel 2)

2013 JudoContact p. 20-20

* **Pion J,** Debuyck G, De Geyter J, Lenoir M. Talent Identificeren in Judo

2013 JudoContact p. 20-20

* Vandorpe B, **Pion J,** Vaeyens R, Philippaerts R, Lenoir M. De zoektocht naar jonge beloftevolle gymnasten, januari 2012, Bloso – VTS redactioneel

* Philippaerts R, **Pion J,** Roeykens J, Meten van Fysieke activiteit, in Fysieke activiteit en voeding, meting en gedragsverandering, Borms J, Van Assche E, **Pion J,** Bloso, Brussel, 1999, pp 51 - 62, ISBN 9789072833044

* Roeykens J, **Pion J,** Philippaerts R, Controle van energieverbruik door fysieke activiteit, in Fysieke activiteit en voeding, meting en gedragsverandering, Borms J, Van Assche E, **Pion J,** Bloso, Brussel, 1999, pp 165 - 182, ISBN 9789072833044

* Van Assche E, Borms J, Maegerman S, Van Meersche R, **Pion J,** Vakoverschrijdende projecten voor fysieke activiteit, voeding en gezondheidsopvoeding op school, in Fysieke activiteit en voeding, meting en gedragsverandering, Borms J, Van Assche E, **Pion J,** Bloso, Brussel, 1999, pp 165 - 182, ISBN 9789072833044

* Goossens R, Dehaene E, Delen J, Lenoir M, **Pion J**, Klassikaal remediëren, in Van Assche E, Borms J, **Pion J,** Eurofit Remediëring, Bloso, Brussel, 1994, pp 199, ISBN 9789072833037

B3

* Lenoir M, Vandorpe B, D'Hondt E, **Pion J,** Vandendriessche J, Vaeyens R, Philippaerts R. KTK-NL Körperkoordinationstest für Kinder (Ernst Kiphard & Friedhelm Schilling) Herwerkte gehernormeerde en vertaalde uitgave van de KTK voor het Nederlandstalig gebied, 2014 , SIG vzw, Destelbergen.

* Borms J, Van Assche E, **Pion J,** Fysieke activiteit en voeding, meting en gedragsverandering, Bloso, Brussel, 1999, pp 239, ISBN 9789072833044

* Van Assche E, Borms J, **Pion J,** Eurofit Remediëring, Bloso, Brussel, 1994, pp 199, ISBN 9789072833037

C1 - C3

* 1er Congrès international sur l'Activité Physique et le Sport chez l'Enfant (CIAPSE) 17 – 18 octobre 2014, Liège

Pion J, Philippaerts R, Vaeyens R, Lenoir M. Generic anthropometric and performance characteristics among elite adolescent boys in different sports (poster presentation)

* Talent Identification Conference "Identifying Champions" April 2nd – 3rd 2014 Doha, Qatar

Pion J, Fransen J, Segers V, Lenoir M. Motor coordination is a key factor for future eltie success in volleyball (poster presentation)

* Dag van de provinciale selectietrainers 8 February 2014, Provinciaal centrum Peerdsbos, Brasschaat

Pion J, Segers V, Lenoir M. Volleybal Talent Identificatie systeem (Voltis)

* Triathlon-World 16 November 2013, Brussels -Expo

Pion J, Segers V, Lenoir M. Screening van talentkenmerken bij triatleten

* Symposium Talent 25 March 2013, Bloso centrum, Sporthotel Gent

Pion J, Debuyck G, Segers V, Lenoir M. The role of maturation in talent selection (oral presentation)

* 38ste BVLO-studiedag 15 november, Gent

Pion J, Lenoir M. Talent detecteren met het Vlaam Sport Kompas

* Annual Sport Science Coaches Symposium 11 February 2012 Bloemfontein, South Africa

Pion J, Lenoir M. Talent identification / Sortkompas (oral presentation)

* 16th annual Congress of the European College of Sport Science 6-9 July 2011: Liverpool, UK: "New horizons from a world heritage city".

Vandorpe B, Vandendriessche J, **Pion J**, Vaeyens R, Lefevre J, Philippaerts R, Lenoir M. The contribution of anthropometric, physical performance and coordinative characteristics to female gymnastics talent identification. 2011. (oral presentation)

* 15th annual Symposium of the Flemish Society for Kinesiology (10th December 2010, Antwerp, Belgium): ‘Motivation and Transpiration.

Vandendriessche J, Vaeyens R, Vandorpe B, **Pion J**, Matthys, Deprez D, Philippaerts R. Comparison of profiles between selected and non-selected soccer players in Flemish top sport school (poster presentation).

* Second World Conference of science and Soccer (8-9 June 2010, Eastern Cape, South Africa)

Vandendriessche J, Vaeyens R, Vandorpe B, **Pion J**, Matthys, Deprez D, Philippaerts R, Comparison of profiles between selected and non-selected soccer players in Flemish top sport school (Belgium) (poster presentation)

* International Congress, Birmingham University, British Gymnastics And Birmigham City Council (30th April – May 1st 2010 Birmigham , UK): The Growing Child in High Performance Sport”.

Vandorpe B, Vandendriessche J, Vaeyens R, **Pion J**, Lefevre J, Matthys S., Philippaerts R, Lenoir M. general motor coordination in elite and sub-elite gymnasts. 2010 (poster presentation).

* 14th annual Symposium of the Flemish Society for Kinesiology (17th December 2009, Leuven, Belgium): “Brain Drain versus Brain Gain”.

Vandorpe B, Vandendriessche J, Lefevre J, **Pion J**, Vaeyens R, Matthys S., Philippaerts R, Lenoir M. The KörperkoordinationsTest für Kinder: Reference values and suitability for 6- to 12- year old children in Flanders. 2009 (Poster presentation)

* 13th annual Congress of the European College of Sport Science 9-12 July 2008: Lisbon, Portugal: “Sport Sciences by the Sea”.

Vandorpe B, Vandendriessche J, **Pion J**, Vaeyens R, Matthys S., Philippaerts R, Lenoir M. Correlation between PE teachers’ judgement of motor skill and results obtained by means of standardized test batteries. (Poster presentation)

* 13th annual Congress of the European College of Sport Science 9-12 July 2008: Lisbon, Portugal: “Sport Sciences by the Sea”.

Vandendriessche J, Vandorpe B, **Pion J**, Vaeyens R, Matthys S., Philippaerts R, Lenoir M. Motor competence in children with mild mental retardation and controls (Oral presentation)