DIAMONDS IN THE ROUGH
SEARCHING FOR HIGH POTENTIAL IN YOUTH TABLE TENNIS PLAYERS

Irene Renate Faber
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Searching for high potential in youth table tennis players

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DIAMONDS IN THE ROUGH

Searching for high potential in youth table tennis players

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Voor Quinten, Floortje en Roos

Opdat zij hun eigen talenten
mogen vinden en vormen
## Contents

**Chapter 1**  
Introduction  

**Chapter 2**  
A first step to an evidence-based talent identification program in the Netherlands:  
A research proposal  
Faber I.R., Oosterveld F.G.J., Nijhuis-Van der Sanden M.W.G.  

**Chapter 3**  
Assessing personal talent determinants in young racquet sport players:  
A systematic review  
Faber I.R., Bustin P.M.J., Oosterveld F.G.J., Elferink-Gemser M.T., Nijhuis-Van der Sanden M.W.G.  

**Chapter 4**  
Can an early perceptuo-motor skills assessment predict future performance in youth table tennis players?  
An observational study (1998-2013)  
Faber I.R., Elferink-Gemser M.T., Oosterveld F.G.J., Twisk J.W.R., Nijhuis-Van der Sanden M.W.G.  

**Chapter 5**  
Does an eye-hand coordination test have added value as part of talent identification in table tennis?:  
A validity and reproducibility study  
Faber I.R., Oosterveld F.G.J., Nijhuis-Van der Sanden M.W.G.  

**Chapter 6**  
The Dutch Motor Skills Assessment (MSA) as tool for talent development in table tennis:  
A reproducibility and validity study  
Faber I.R., Nijhuis-Van der Sanden M.W.G., Elferink-Gemser M.T., Oosterveld F.G.J.  
Chapter 7
Revision of two test items of the Dutch Motor Skills Assessment measuring ball control in young table tennis players: A reproducibility and validity study
Faber I.R., Elferink-Gemser M.T., Oosterveld F.G.J., Nijhuis-Van der Sanden M.W.G.

Chapter 8
Can perceptuo-motor skills assessment outcomes in young table tennis players (7-11 years) predict future competition participation and performance?: An observational prospective study
Faber I.R., Elferink-Gemser M.T., Faber N.R., Oosterveld F.G.J., Nijhuis-Van der Sanden M.W.G.

Chapter 9
High potential in table tennis from the perspectives of elite players and their youth trainers:
An exploratative qualitative study.
Faber I.R., Oosterveld F.G.J., Heuvel S. van den, Bustin P.M.J., Elferink-Gemser M.T., Nijhuis-Van der Sanden M.W.G.
*Submitted for publication.*

Chapter 10
General discussion

Summary

Samenvatting

Dankwoord

Curriculum Vitae

List of Publications

RIHS PhD Portfolio
Chapter 1

Introduction

Objective of the thesis:
To gain insight into the concept of high potential for elite performance in table tennis by searching and assessing personal talent determinants in youth players (6-12 years).
CHAPTER 1

In pursuit of excellence

In many nations and organisations all around the world, people pursue excellence in many domains. Success or failure is decided by the ability of the so-called ‘talent’ of individuals to thrive within certain contexts. Talent is suggested to be an absolutely crucial factor in the economic struggles taking place in the 21st century (Ankersen, 2012). Consequently, one main objective is to find ‘high potentials’, who have the best chance to succeed. In this perspective, numerous questions arise: What is talent? Does this imply universal characteristics or is this specific for a certain field? Is it time-dependant? Can we recognize this at an early stage and how? Is it possible to ensure an efficient and effective development to success?

Of all global ‘talent competitions’, the pursuit of excellence in sports is probably the most obvious. Triumphs in sports can positively contribute to a nation's political and economical position, health status and well-being as successful elite players serve as a nation's representatives and as role-models for fellow citizens. Many governments in partnerships with national sport associations use talent development programmes to support youth players to develop into elite players. They try to improve their success rate by selecting players with the highest potential for success in a specific sport through talent identification, monitoring the development of these players and providing them with new or additional training methods and social support. Selecting and monitoring players for talent development programmes, however, is extremely difficult since long-term success is unpredictable due to the multidimensionality of elite performance characteristics and the individual nature of development and learning curves (Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011; Philips, Davids, Renshaw, & Portus, 2010; Unierzyski, 2006).

At this moment, ranking position and scout's observations often form the basis of selection criteria of talent development programmes. Although short term successes might be easily and accurately predicted by current ranking positions, it is suggested that ranking positions of youth players are not able to reflect the players’ full potential (Brouwers, De Bosscher, & Sotiriadou, 2012; Heller, 2008; Gagné, 2004; Reid, Crespo, Santilli, Miley, & Dimmock, 2007). Current personal characteristics in youth players, influenced by growth, maturity and the possibilities for training and competition (Coelho E Silva et al., 2010; Malina, Cummings, Morano, Barron, & Miller, 2005), can provide a temporary advantage or disadvantage in competition. Consequently, based on ranking position alone, it is difficult to determine if these results reflect a player’s full potential adequately. Nevertheless, the success of talent development programmes will probably increase most from plausible long term predictions as it takes an investment of many years for both the player and the environment to reach elite level. Furthermore, since performance itself is influenced by individual differences in growth, maturation, development and learning curves, training experiences, competition participation and environmental factors, scouts have difficulties to find the high potential youth players for elite sports. Although measuring potential for elite sports in a developing child is challenging, innovative solutions to find 'diamonds in
the rough’ are suggested to improve the success rate of talent development programmes (Gagné, 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Vandorpe et al., 2012).

This thesis contributes to the search of high potentials in sports by exploring crucial indicators for success at an adult age and how to assess them in youth players. It mainly focuses on table tennis, which can be considered as a case in the field of sports. Nevertheless, the findings are considered also applicable to other racquet and ball sports on the basis of task-similarities during development. Moreover, the methods used to get a grip on the concept of high potential in a specific field might also be useful in a broader context. As such, this thesis is considered relevant to professionals and scientists interested in talent identification and development in a variety of fields, but especially in the field of racquet and ball sports.

Table tennis

Global trends
Table tennis is a popular sport all around the world with the largest number of competitive players in Asia and Europe. Although no exact up-to-date statistics are available, it was estimated in 1995 that almost 300 million people play table tennis worldwide (Sklorz & Michaelis, 1995), including 40 million competitive table tennis players (http://www.olympic.org/table-tennis). Table tennis is an international, socially attractive sport, relatively cheap, practicable for players of all ages and easily accessible to many people. Although table tennis is practiced in many countries, China appears to have a monopoly on winning gold medals in world-level competition (http://www.ittf.com). Even in Europe, female athletes of Chinese origin dominate the top 10 ranking (http://www.ettu.org/; Heller, 2008). If countries in Europe or other continents want to be serious competitors at international table tennis events with native players, changes in policies and educational programmes seem inevitable. Additionally, only relying on deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993) for winning medals at world championships or the Olympic games seems outdated as training programmes in table tennis have been maximized and the sport has become highly professionalized. Innovations for finding ‘high potential’ players at a young age might help countries aiming to compete at the world’s highest level.

Sport specifications
Table tennis is one of the major racquet sports and widely regarded as one of the fastest sports in terms of game speed (Abernethy, 1991; Lees, 2003). It is an individual sport that can also be played in pairs, using a racquet / bat to hit the upcoming ball (Ø 40mm) that approaches the player from the front. The player(s) need(s) to hit the ball over the net to put it onto the opponent’s side of the table tennis table and try to establish that the opponent(s) will not be able to return it successfully (Lees, 2003). Match and rally duration can vary, but most matches last between 20-60 min including rallies of 3-10 s with a work-to-rest ratio of
approximately 1:2 (Kondrić, Zagatto, Sekulić, 2013; Lees, 2003). Matches in table tennis are characterised by repetitive efforts of alternating short high-intensity bouts during the rally and recovery bouts between the rallies interrupted by resting periods of longer duration between games. Such match activity appeals predominantly on a player’s anaerobic capacity, while the aerobic system supports recovery (Kondrić et al., 2013; Lees, 2003). Since table tennis has developed into fast paced, explosive sport, the dependence on physical abilities is considerable (Lees, 2003).

**Excellence in table tennis**

Players aiming to excel in table tennis need to develop outstanding motor control including coordination in perceptuo-motor skills to control the ball during services and returns (Girard & Millet, 2009; Limooch, 2006). Moreover, anticipatory skills are required to be able to make quick and responsive adaptations to the continuously changing conditions related to the large variety of the flight and rotation of the (upcoming) ball, the playing styles of opponents and environmental conditions (Abernethy, 1991; Ak & Koçak, 2010; Aknar, Devrimes, & Kirazci, 2012; Bastieans, 2006; Horsch, 1990; Kovacs, 2007; Sève, Saury, Theureau, & Durand, 2002). Additionally, they must learn to master outstanding tactical skills and cope with the physical demands (Kondrić, Zagatto, & Sekulić, 2013; Lees, 2003; Munivrana, Petrinović, & Kondrić, 2015a; Munivrana, Furjan-Mandić, & Kondrić, 2015b; Raab, Masters, & Maxwell, 2005). Inseparable from these more physical aspects, mental aspects, such as concentration and mental toughness, need to be optimised during the extensive development programme. Not to mention, volition, self-regulation and social skills are crucial factors for persevering throughout this training process for many years (Chu, Chen, Huang, & Hung, 2012; Jonker, Elferink-Gemser, & Visscher, 2010; Lees, 2003; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Lubbers, 2006).

**Talent development**

Table tennis is generally acknowledged as an early entry sport in which players aiming to excel need to start at an early age (5-8 years). From this age, players develop the perceptuo-motor skills considered fundamental in developing outstanding technical qualities specific to table tennis (German Table Tennis Association, 2008). The optimal automation of technical skills (i.e. strokes) also entails better possibilities for a player to execute tactical strategies (Kannekens, Elferink-Gemser, & Visscher, 2011). The need for an early start is supported by studies identifying sensitive periods for learning motor skills from five years till the pubertal growth (Knudsen, 2004; Watanabe, Savion-Lemieux, & Penhune, 2007). In addition, most well-known elite players started early and played competitions before the age of 10 years. Accordingly, the search for high potential youth players in table tennis starts at about an age between 6 to 12 years (Limooch, 2006). Subsequently, deliberate practice containing an enormous amount of training has to be carried out, which considerably exceeds the 10,000 hours-rule for expertise (Ericsson, Krampe, & Tesch-Römer, 1993). As there are no short-cuts for excellence in table tennis, players need to accomplish this training challenge without guarantees of (inter)national success. After playing regional and
national level, world’s elite players reach the international level during junior age (14-18 years) and show their peak performance between the ages of 18-24 years for Asiatic players and between 22-32 years for players from other continents (www.ittf.com).

Challenges for practice

The Netherlands Table Tennis Association (NTTA) needs to deal with the global trends. As the Netherlands is only a small country, with a relatively small number of table tennis players and a low budget, identifying the true ‘high potentials’ seems vital for competing at the highest level. Wrong choices in selecting youth players for the association’s talent development programme will lead to failure and is a waste of time and of financial resources. Since the NTTA wants to make accurate selections in youth players already at a young age, they want to capture the potential of a child for future success. As the NTTA considers that table tennis performance alone does not present the full potential of a child, they are searching for other methods. In 1998, they developed a perceptuo-motor skills assessment measuring perceptuo-motor skills. With this assessment the NTTA expected to better compare youth players with differences in table tennis experiences regarding their perceptuo-motor potential. Although this assessment has been used since 1998, the NTTA never evaluated the reproducibility and validity of this assessment for talent developmental purposes. Moreover, the assessment was never extended with test items assessing other aspects like for example mental toughness, concentration and self-regulation. Consequently, this study was set-up in cooperation with the NTTA to support the NTTA in further development based on scientific evidence.

Scientific quality standards

As this thesis focuses on the determinants of ‘high potential’ in sports and methods for assessing these in youth players, it must be acknowledged that the empirical research included is underpinned by two assumptions highlighted by Cobley and colleagues (Cobley, Schorer & Baker, 2012). The first assumption is that ‘high potential’ is identifiable and therefore measurable. Yet, it is unknown in many sports which qualities c.q. personal talent determinants to look for at an early age or stage of development. The second assumption is that adult performance can be predicted by earlier performance. This is complicated by the fact that development and learning curves are often not linear by nature. Moreover, the sport itself also changes and evolves over time, which implies that proper talent identification and development should be based on a realistic vision about future table tennis. If not, youth players are selected and educated following current standards and will probably not be able to match future requirements. Being aware of our limitations when interpreting results is important. However, new findings may improve the understanding of sports’ talents.
Conducting research according to the latest scientific quality standards is important for drawing valid conclusions from the results. For that reason, an up to date theoretical framework was used and the design and methodological issues of the studies in this thesis are carried out by following the current standards. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement is used for reporting the systematic review where possible (Moher, Liberati, Tetzlaff, & Altman, 2009). Moreover, measurement properties, mainly reproducibility and validity, of the instruments studied are evaluated with the COnsensus-based Standards for the selection of health status Measurement INstruments (COSMIN) (Mokkink et al., 2010). Finally, the COnsolidated criteria for REporting Qualitative studies (COREQ) is utilized to report the qualitative study (Tong, Sainsbury, & Craig, 2007).

Objective and outline of the thesis

The aim of this thesis is to gain insight into the concept of high potential for elite performance in table tennis by searching and assessing personal talent determinants in youth players (6-12 years).

In chapter 2, a research proposal including theoretical considerations is presented, which is used for the design of the studies conducted as part of this thesis. Both top-down (quantitative) and bottom-up (qualitative) methods are described for the purpose of this thesis.

In chapter 3, a systematic review presents a theoretical framework and a state-of-the-science overview on the instruments available in racquet sports to assess personal talent determinants in youth players. Special attention is paid to the validity of these instruments for talent developmental purposes.

Chapter 4 through 8 describe the development and evaluation of a perceptuo-motor skills assessment to measure perceptuo-motor skills in youth table tennis players (6-12 years) as a part of a talent development programme. The reproducibility, the ability to discriminate between high potential players and others and the predictive value of the assessment are evaluated. Chapter 4 is based on data from 1998-2013 to evaluate the predictive value of the four test items of the motor skills assessment that were used throughout this period. Chapter 5 presents the study on the development of a new eye hand coordination test. Chapter 6 contains the first evaluation of the motor skills assessment consisting of eight test items, including an analysis regarding the reproducibility per test item, internal consistency, latent variables (principal component analysis) and concurrent validity. In chapter 7 a study on the reproducibility and discriminative validity of two revised test items is reported. Chapter 8 contains an observational prospective study to provide an evaluation of the predictive value of the current motor skills assessment.
As the configuration of ‘high potential’ had to be unravelled further, chapter 9 describes a qualitative study in which hidden knowledge regarding this topic from elite players and their youth trainers was uncovered. The findings of this study give directions for further studies on ‘high potential’ in sports.

In chapter 10, the findings of the included studies are combined into a general discussion. This chapter also contains the main conclusions and directions for professionals and scientists for future research and practice, respectively.

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introduction
Chapter 2

A first step to an evidence-based talent identification program in the Netherlands: A research proposal

Irene R. Faber
Frits G.J. Oosterveld
Maria W.G. Nijhuis-Van der Sanden

*International Journal of Table Tennis Science, 2012, 7, 15-8*
Abstract

Talent identifications programs are developed for several sports in different countries around the world to improve the chance to excel during important sports events like the Olympics or World Championships. Not only elite sports at world class level but also the recreational level will benefit from talent identification programs. For a small country as The Netherlands, it is desirable to develop a good talent identification program to keep up with international level and to improve the connection between table tennis and recreational sports or non-athletes looking for a sport that fits them well. Because the key-factors which determine talent for table tennis are unknown, research to get a scientific fundament for a talent identification system for table tennis sports is desirable. This article presents a long-term research project (PhD) which is set-up by the Netherlands Table Tennis Association (NTTA) together with Saxion University of Applied Science and IQ Healthcare of the Radboud University Nijmegen in The Netherlands. The main purpose of this project is to find sport-specific determinants which play a key-role in talent identification in table tennis using a combination of top-down and bottom-up approaches.

Preliminary results from the top-down approach are already available from reliability and validity studies on the talent identification assessment (TIDA) which is used by the NTTA. Analysis show mainly good reliability for the test items separately and for the TIDA as a whole. Concurrent validity is partly confirmed for the TIDA, however further analysis are necessary. This research project can make an important step to an evidence-based talent identification program which benefits table tennis and other sports at elite and recreational level.

Keywords: table tennis, talent identification, evidence based
Introduction

Talent identification programs are used to identify talented athletes in time and to succeed at world class level. Besides the benefits for elite sports, talent identification in sports can be a helpful tool to increase sport participation in an open population and to reduce drop-outs by providing an optimal connection between sports, talents and personal preferences also on an amateur level (Kondric, 1996; Nederlands Olympisch Comité * Nederlandse Sport Federatie, 2007).

In literature suggestions are made about the determinant factors in sports which can predict success and should be used for talent identification. Models propose factors from several areas such as: ‘anthropometry’, ‘motor skills’, ‘mental skills’, ‘physical qualities’ and ‘contextual factors’ (Bosch van den & Cocq de, 2006; Elferink-Gemser, 2005; Kondric, 1996; Régnier, Salmela, & Russell, 1993; Reilly, Williams, Nevill, & Frank, 2000), Fig. 1.

Although key-predictors are recognized for some sports (Bös & Schneider, 1997; Rossum & Gagné, 1994; Rossum, 1996; Rossum, 2006), most sports still search for these specific determinants. Therefore, it has been recommended that each sport should develop a sport-specific talent identification program (Bosch van den & Cocq de, 2006; Elferink-Gemser, 2005; Kondric, 1996; Régnier et al., 1993; Reilly et al., 2000).

Earlier research about table tennis revealed that trainers / coaches of the Dutch national selection found the presence of ‘motor skills’ the most important area to succeed, followed by mental and physical fitness (Rossum & Gagné, 1994). Descriptions about table tennis sports from several authors proposed the following motor skills and physical traits as important for good table tennis performance: coordination, visual perception, control of arm and head movements, technical knowledge, a good sense of the game, ball control, good cardio-respiratory endurance, upper body- and hand strength in combination with good joint and muscle flexibility (Horsch, 1990; Kondric, Furjan-Mandic, Kondric, & Gabaglio, 2010; Lees, 2003; Raab, Masters, & Maxwell, 2005; Rodrigues, Vickers, & Williams, 2002; Sørensen, Ingvaldsen, & Whiting, 2001).
In contrast, Limoochi reported that of 40 international level coaches 36% ranked anthropometric factors as most important for talent identification followed by psychological factors (33%) and psychomotor factors (25%). From these areas ‘standing height’, ‘intelligence’ and ‘motivation’ were proposed to be key-factors, respectively. Only 11% of the coaches choose physical motor factors as most important (Limoochi, 2006). Nevertheless, it must be remarked that because no specific definitions or way of measurements were given for each factor in this study, it is quite hard to make a good interpretation and comparison with other studies.

Concerning the mental skills, Chu et al. reported, using a qualitative approach, that the optimal mental states for ten elite table tennis players in Taiwan were characterized by concentration, self-confidence, positive thinking, emotional management and motivation (Chu, Chen, & Hung, 2011). In addition, Lopez & Santelices (2011) concluded from data (Manchester Personality Questionnaire) of elite table tennis athletes from the Philippines that personal characteristics of originality, rules consciousness, assertiveness, competitiveness, conscientiousness, achievement and resilience should be taken into account for effective recruitment of talents.

However, at this moment little scientific evidence is available about the determinants which are key-factors in table tennis and predict success on world class level. This has to be found out, before the next step ‘how to measure them’ can be made. Our main research question therefore is: Which sport-specific determinants are important for identifying table tennis talent in youth players (7-12 years)? Research which combines top-down and bottom-up approaches is proposed to be an appropriate way to answer this question, Fig. 2.

![Figure 2. Top-down and bottom-up](image-url)
Research proposal

Top-down approach

The top-down approach is characterized by gathering empirical evidence using established methods to confirm or reject prior hypotheses (Régnier et al., 1993). Univariate and multivariate analysis methods in retrospective data will be used to answer the research question.

The Netherlands Table Tennis Association (NTTA) developed a talent identification program to organize and structure talent identification. The national talent day is one of the events in this program. During the national talent day of the NTTA young table tennis athletes are tested for their table tennis talents. Therefore these children participate in a tournament while being observed by scouts and their motor skills are tested using a talent identification assessment (TIDA), Table 1.

Data were collected from 1998 till 2010 and include the test results and tournament ranking of more than 1300 youth players between 5-12 year. Moreover the national rankings of the youngsters are available to follow the performance level of these youth players over years. This data-set will be used for the analysis of the top-down approach and mainly consists of performance measurement of motor skills (Fig.1). Sport-specific determinants for talent can be found by comparison of the well performers and poorly performers to learn more about talent identification in table tennis.

In addition to above, the reproducibility of the TIDA was investigated analyzing internal consistency and test-retest reliability (Ekman, Faber, Oosterveld, & Nijhuis - Van der Sanden, 2011) and new test items were developed to cover all specific traits which were suggested for talent identification by the NTTA experts. For the newly developed items validity was investigated by comparing talented and non-talented youth players and also a test-retest design was used to study reliability.

Table 1: Current test items of the TIDA (Talent Identification Assessment)

<table>
<thead>
<tr>
<th>TEST ITEM</th>
<th>SHORT DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint</td>
<td>Pick-up and bring back 6 table tennis balls as fast as possible (pyramid shape sprint)</td>
</tr>
<tr>
<td>Agility</td>
<td>Getting through a circuit as fast as possible; over a gymnastics cabinet and under a low hurdle.</td>
</tr>
<tr>
<td>Vertical Jump</td>
<td>Jumping as high as possible.</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>Sideward dribbling through a zigzag circuit.</td>
</tr>
<tr>
<td>Aiming at target</td>
<td>Aiming at a target with bat and ball.</td>
</tr>
<tr>
<td>Ball skills</td>
<td>Aiming a target with different balls (football, tennis ball, table tennis ball) using one bounce.</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>Throwing a table tennis ball as far as possible.</td>
</tr>
<tr>
<td>Eye hand coordination</td>
<td>Throwing and catching a table tennis ball against a vertical table as often as possible in 30 seconds using alternatively the left and right hand.</td>
</tr>
</tbody>
</table>
CHAPTER 2

Bottom-up approach

In the bottom-up approach elements for solution come from the collective wisdom, the rich anecdotal evidence, and the language of the sport performers themselves. Régnier et al. (1993) report this as an attempt to find out what features talented athletes cite in any specific area to explain their exceptional performance. Also the experiences of expert trainers / scouts could be of great value to find sport-specific determinants for table tennis.

Qualitative studies are now designed to gain more insight in the vision and experiences of elite players and top trainers / scout on talent identification and development. Semi-structured interviews will be held to collect data. A content analysis will show whether the TIDA covers most important motor skills and physical traits and which other determinants should be taken into account in future.

Preliminary results

At this moment only preliminary results are available.

Reliability studies have been conducted on the used test items. As a whole the TIDA has a good reliability and also per test items mainly good reliability has been shown (Ekman et al., 2011).

The analyses for validity and to find sport specific determinants are now in process and the final results are expected at the end of 2011. From the first analysis the validity of the test items ‘speed while dribbling’, aiming at target, ball skills and ‘eye hand coordination’ seem promising; the concurrent validity (Faber, Oosterveld. & Nijhuis-Van der Sanden, 2011) or the ability to discriminate between talented and less-talented youth players seems to be confirmed. However, further analysis and corrections for confounders are needed to make fair conclusions.

New data for the bottom-up approach still need to be collected and analysed. This research will be carried out in 2012 and results are expected at the end of 2012.

Discussion

A talent identification program which is based on scientific evidence can be of great value for the table tennis sports. Of course, individual exceptions which do not fit the criteria of such a program always remain. However, elite sports and also sport at a recreational level are expected to benefit from good talent identification by decreasing the chance to miss talent.

Since Van Rossum and table tennis experts (Horsch, 1990; Kondric et al., 2010; Lees, 2003; Raab et al., 2005; Rodrigues et al., 2002; Sørensen et al., 2001) showed that motor skills
and physical fitness are important traits in table tennis, it seems reasonable to investigate the value of the TIDA used by the NTTA. Moreover, talent identification which only consists of national ranking seems inappropriate, because ranking is influenced by the amount and quality of training. Especially in a small country as the Netherlands ranking will not provide the necessary information and talents could be missed. Furthermore, the nowadays system of scouting is not transparent enough and personal preferences of scouts might influence the results. A systematic approach of testing with valid and reliable tools on sports-specific determinants during a talent identification program is desirable to objectively select talents (Kondric, 1996).

To obtain fair results for talent identification some required conditions are proposed when using a TIDA to test motor skills and physical fitness. First of all, the test items of the TIDA should cover all traits which play a key-role in table tennis. Secondly, to avoid the influence of training on the performance outcome, the test items should consist of uncommon tasks which are more or less new for everyone, but which are correlated to table tennis competencies. Therefore, table tennis tasks as returning a service, playing forehand topspin or the specific table tennis tests that Katsikadelis and colleagues used seem inappropriate (Katsikadelis, Pilianidis, Douda, & Tokmakidis, 2006). Then the tasks must motivate youth players in the age between 7-12 years to perform at their bests. So the tasks should be challenging and quite fun to do. Of course all test items and the TIDA as a whole must also meet the psychometric requirements for reproducibility, validity and responsiveness. Finally, for a good interpretation it is desirable to have norm values which are age and gender corrected (Kondric, 1996).

Although the first analyses (Ekman et al., 2011) are promising, for reliability and validity further research is necessary to find the complete set of sport-specific determinants for table tennis. A critical reflection about the construct of the TIDA and the predictive value of the test items are essential to make straight conclusions.

Besides motor skills and physical traits also mental aspects and maybe other personal (anthropometric) and environmental factors must be taken into account for talent identification in table tennis (Chu et al., 2011; Limoochi, 2006; Lopez & Santelices, 2011). A good talent identification system includes sport-specific factors from different areas / domains (Fig. 1). Although some research has been conducted in the Philippines and Taiwan to identify some of the mental / personal key-factors (Chu et al., 2011; Lopez & Santelices, 2011), the question arises whether these results can be extrapolated to countries in West-Europe. This also applies to the results of Limoochi’s study (Limoochi, 2006). Cultural aspects and the norms and values of countries differ quite a lot, which can influence the results. A bottom-up approach with semi-structured interviews of elite players from the Netherlands and other West-European countries would add more insight which determinants are important for talent identification.

In conclusion, this research project aims to make a step to an evidence-based talent identification program which benefits sports at elite and recreational level. A combination of
CHAPTER 2

Top-down and bottom-up research provide results a complete insight in the determinants which play a key-role for table tennis talents. Results from this study can be especially used for table tennis, however other racket sports also might profit, too.

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Chapter 3

Assessing personal talent determinants in young racquet sport players: A systematic review

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Abstract

Since junior performances have little predictive value for future success, other solutions are sought to assess a young player’s potential. The objectives of this systematic review are (1) to provide an overview of instruments measuring personal talent determinants of young players in racquet sports, and (2) to evaluate these instruments regarding their validity for talent development. Electronic searches were conducted in PubMed, PsychINFO, Web of Knowledge, ScienceDirect, and SPORTDiscus (1990 to 31th March 2014). Search terms represented tennis, table tennis, badminton and squash, the concept of talent, methods of testing and children. Thirty articles with information regarding over 100 instruments were included. Validity evaluation showed that instruments focusing on intellectual and perceptual abilities, and coordinative skills discriminate elite from non-elite players and/or are related to current performance, but their predictive validity is not confirmed. There is moderate evidence that the assessments of mental and goal-management skills predict future performance. Data on instruments measuring physical characteristics prohibit a conclusion due to conflicting findings. This systematic review yielded an ambiguous endpoint. The lack of longitudinal studies preclude verification of the instrument’s capacity to forecast future performance. Future research should focus on instruments assessing multidimensional talent determinants and their predictive value in longitudinal designs.

Keywords: tennis, table tennis, badminton, aptitude, gifted children
Introduction

Tennis, table tennis, badminton and squash are considered the four major racquet sports. Although the context, materials and rules of the games may differ between these sports, there is an overlap of the main challenges for players competing. They are all individual sports that can also be played in pairs, using a racquet to hit the upcoming ball or shuttle that mainly approaches the player in front. The player(s) need(s) to hit this target to put it onto a demarcated play-field and try to establish that the opponent(s) will not be able to return it successfully (Lees, 2003). Match and rally duration can vary within and between the racquet sports; nevertheless most matches last between 20 and 90 min including rallies of 3-10 s with a work-to-rest ratio between 1:2 and 1:5 (Kondrič, Zagatto, Sekulić, 2013; Kovacs, 2007; Lees, 2003; Manrique & González-Badillo, 2003; Sharp, 1998). Matches in racquet sports are characterised by repetitive efforts of alternating short high-intensity bouts during the rally and recovery bouts between the rallies, and interrupted by resting periods of longer duration between games. Such match activity appeals predominantly on a player’s anaerobic capability, while the aerobic system supports recovery (Kondrič et al., 2013; Kovacs, 2007; Manrique & González-Badillo, 2003; Sharp, 1998). Since the racquet sports have developed into fast-paced, explosive sports in the last decades, the dependence on the physical abilities increased (Lees, 2003). The repetitive nature of racquet sports combined with the high game speed i.e. speed of the strokes can lead to repetitive strain injuries, especially in tennis (Kovacs, 2007; Lees, 2003).

To excel in these sports, players need to develop outstanding motor control (including coordination in perceptuo-motor skills to control the ball or shuttle during services and returns by using a racquet), anticipatory skills (Abernethy, 1991; Ak & Koçak, 2010; Akpinar, Devrilmes, & Kirazci, 2012; Horsch, 1990; Kovacs, 2007) and be able to withstand the physical demands (Banzер, Thiel, Rosenhagen, & Vogt, 2008; Chin, Steininger, So, Clark, & Wong, 1995; Hjlem, Werner, & Renstrom, 2012; Kondrič et al., 2013; Kovacs, 2007; Lees, 2003). Moreover, during the match they must be able to make very quick adaptations to the continuously changing conditions related to the large variety of the flight and rotation of the (upcoming) ball or shuttle, playing styles of opponents and environmental conditions (e.g. temperature, humidity, wind, racquet materials and playing surfaces) (Bastiaans, 2006; Sève, Saury, Theureau, & Durand, 2002). Finally, players need highly developed tactical skills, concentration and mental toughness throughout a match and also volition, self-regulation and social skills to persevere during the extensive development programme (Chu, Chen, Chen, Huang, & Hung, 2012; Lees, 2003; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Lubbers, 2006).

Racquet sports are often acknowledged as early specialisation sports in which players aiming to excel need to start at an early age (5-8 years). From this age, players develop perceptuo-motor skills and subsequent sport-specific technical skills. The need for an early specialisation is supported by studies identifying sensitive periods for learning motor skills
5 years till the pubertal growth (Knudsen, 2004; Watanabe, Savion-Lemieux, & Penhune, 2007). In addition, most well-known elite racquet sport players started early and played competition before the age of 10 years. Subsequently, international level was reached during junior age (14-18 years) and peak performance between the age of 20 and 32 years.

Many racquet sport associations use talent development programmes to help young, non elite players to develop into elite players. They try to improve their success rate by selecting players with the highest potential for their sport through talent identification in children that are already active in the racquet sport, monitoring the development of these players, and establishing new and/or additional training methods. Selecting and monitoring players for these talent development programmes, however, is extremely difficult due to the multidimensionality of the performance characteristics in elite sports, the individual nature of development and learning curves, and the unpredictability of long-term success in young players (Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011; Philips, Davids, Renshaw, & Portus, 2010; Unierzyński, 2006). The question that arises is: which criteria in a young player can be used for talent development i.e. for selection and monitoring procedures? And how can these criteria be measured properly?

At this moment, in competition with other countries, performance results, e.g. competition outcomes and ranking, are used to select and monitor young players. Children need to have gathered enough competition points or a certain ranking position to qualify for a specific team and/or training level. However, as in many other sports, junior performance seems to have little predictive value for future success in racquet sport (Brouwers, De Bosscher, & Sotiriadou, 2012; Heller, 2008; Reid, Crespo, Santilli, Miley, & Dimmock, 2007). Ranking positions at a young age are influenced to a large extent by differences in maturation and growth processes, development and learning curves, training experience (i.e. training hours and quality of the training), the degree of participation in competitions or tournaments and environmental factors (e.g. competition organisation and parental involvement) (Malina, Cummings, Morano, Barron, & Miller, 2005; Silva et al., 2010). Current personal characteristics of young player can provide a temporary advantage or disadvantage in competition, but probably will not predict future performance. Consequently, based on performance results alone, it is difficult to determine whether these results reflect a player’s maximal potential adequately. Decisions solely based on such criteria appear inadequate on long term and will probably waste high-potential players, which highlights the relevance of this review. Criteria based on the maximum potential of a player are suggested to be more appropriate (Gagné, 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Vandorpe et al., 2012). It is complicated, however, to measure personal talent determinants in a developing child.

Gagné (2010) proposed a pathway for talent development in his Differentiated Model of Giftedness and Talent 2.0 (DMGT 2.0) (Figure 1). In his view, natural abilities need to be developed into talents, where the intrapersonal and environmental catalysts contribute to a large extent to efficiency and efficacy of the developmental process. Both natural abilities and intrapersonal catalysts, i.e. the personal talent determinants, are characteristics
in a player reflecting his / her gifts and his / her developmental ability, respectively. So, to identify and monitor a player’s potential, characteristics of both areas, including physical, mental and goal management aspects, need to be assessed, while taken into account the association between these aspects and the un-exclusiveness of the measurements. This is in accordance with current proposals of multidimensional approaches of talent development including the individual nature of pathways to expertise (Elferink-Gemser et al., 2011; Philips et al., 2010). This systematic review focuses on the aspects in racquet sport players.

Figure 1. The Differentiated Model of Giftedness and Talent 2.0 (Gagné, 2010) (authorization given by François Gagné, personal communication)

Many racquet sport associations try to find solutions for this and use test batteries to assess different personal talent determinants of their young players. To use such instruments and interpret the results correctly, knowing more about their measurement properties is essential (Faber, Nijhuis-Van der Sanden, & Oosterveld, 2012, Mokkink et al., 2010; Morrow, Jackson, Disch, & Mood, 2011). Besides reproducibility issues, these instruments must meet specific validity requirements concerning talent development purposes. This review focuses on the latter with respect to the four major racquet sports. Only when instruments meet validity requirements they can be of value for talent development in sports (Faber et al., 2012; Gagné, 2004; Morrow et al., 2011; Vaeyens et al., 2008). The inclusion of the rac-
quet sports in one review seems sensible due to the similarities between tennis, table tennis, badminton and squash concerning the tasks’ requirements, match performances and personal talent determinants as described in the first part of the introduction. Even though profiles of elite players differ between racquet sports and instruments can be more specific for one of the sports, the talent determinants that are assessed are expected to be relevant for all racquet sports. Consequently, it is expected to enrich its content, although it is acknowledged that national talent programmes generally focus on one specific sport. The goal of this systematic review is to provide a state-of-science overview of existing instruments measuring personal talent determinants of young players that are actively participating in the four major racquet sports. Moreover, these instruments are evaluated with regard to their validity for talent development, i.e. the selection and/or monitoring, in racquet sports. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement was used for reporting where possible (Moher, Liberati, Tetzlaff, & Altman, 2009).

Methods

Systematic search

Electronic database searches were conducted in PubMed, PsychINFO, Web of Knowledge, ScienceDirect and SPORTDiscus, limited to published peer-reviewed papers from 1990 till 31 March 2014. Search terms for all data bases represented the sports of tennis, table tennis, badminton and squash, the concept of talent, and methods of testing. Searches were restricted to children (<18 years) using additional search terms or limitations, depending on the settings of the database. Detailed search strategies of the databases included are presented in Online Resource 1. Because a comprehensive review was intended with the purpose to find as many references to different methods of testing as possible, all study designs were included. Language was not restricted during the searches. Duplicates were removed and studies that were not available as full-length publications, but only as an abstract, were excluded.

Titles and abstracts retrieved from the systematic search were independently screened by two investigators (IF and PB). Studies were included if (1) the focus was on measurements for talent development; (2) tennis, table tennis, badminton and/or squash were subject of the study; (3) the investigated sample included healthy children (≤ 18 years) and (4) they were written in English, Spanish, French, German or Dutch. Studies were excluded if (1) participants were non-healthy children or adults; (2) they discussed the predictive value of competition results or ranking junior racquet sport performances on adult successes without information on personal talent determinants; or (3) they concerned factors beyond the individual player, i.e. environmental involvement. When inclusion could not be determined from the title or abstract, the full-text articles were retrieved and screened. After an independent evaluation by both investigators, consensus was reached about inclusion, if not the research group was consulted. Reference lists of all relevant articles were manually checked for additional papers published using the same criteria of inclusion and exclusion.
Quality check
The overall methodological quality of the included articles was assessed using the critical review form for quantitative studies by Law et al. (1998) counting 16 items. Articles were assessed with regard to purpose (item 1), relevance of background literature (item 2), appropriateness of the study design (item 3), sample included (items 4 and 5), informed consent procedure (item 6) outcome measures (item 7), significance of results (item 10), analysis (item 11), clinical importance (item 12), description of drop-outs (item 13), conclusion (item 14), practical implications (item 15) and limitations (item 16). Item 8, about the validity of the measures in the study, was rated as indeterminate in this phase of the research because the validity of the instruments for talent development is a main topic of this review and will be investigated in more detail in the next step as described in the section ‘Validity evaluation’. Item 9, about details of the intervention procedure, was not applicable because none of the studies included interventions. The outcomes per item were 1 (meets criteria), 0 (does not meet the criteria fully), NA (not applicable) and ? (indeterminate rating) (Wierike, Sluis, Akker-Scheek, Elferink-Gemser, & Visscher, 2013). To make a fair comparison between studies of different designs, the decision was taken to calculate a percentage score as a final score in which the sum of the score of all items was divided by the number of relevant scored items for that specific research design. We considered articles with a score ≤ 50% as low methodological quality, between 51% and 75% studies as good methodological quality and >75% as excellent methodological quality. This classification was established by the authors of this review. Yet, the threshold of ≤ 50% for low methodological quality corresponds to the cut-off score used by Wierike et al. (2013).

Validity evaluation
All instruments relevant to the topic of this review and the evidence regarding validity were extracted from the articles included. The natural ability and the intrapersonal catalyst domains of the DMGT 2.0 of Gagné (2010) (Figure 1) were used to classify all instruments measuring possible personal talent determinants and to present an overview. The description of the categories of the DMGT 2.0, including key terms, and the descriptions of the original articles gave direction for classification. When instruments measured several factors simultaneously, the factor that was emphasised most during measurement was decisive for classification. The following three hypotheses were checked with regard to each instrument to evaluate the validity of the instruments for talent development purposes:

1. The test is able to discriminate between elite and non-elite players.
2. The test is able to predict future performance.
3. The test provides a direction for talent development by profiling and/or monitoring players.

To indicate the specific level of evidence regarding these validity hypotheses, Box F ‘hypothesis testing’ of the COIncensus-based Standards for the selection of health Measurement INstruments (COSMIN) checklist was used (Mokkink et al., 2010). This box of the COSMIN checklist makes rating the methodological quality of studies possible with regard to the va-
Validity aspects described, using 10 items with a 4-point rating scale: excellent, good, fair and poor. Subsequently, the methodological quality per study is obtained by taking the lowest rating of any item ('worst score counts'). All studies are included for the data syntheses. Table 1 demonstrates how the final ratings regarding the validity of all instruments found in this review were determined per hypothesis using COSMIN. As the validity of an instrument depends on reliability, the information about the above-mentioned reliability aspects from the quality check of Law et al. (1998) was also taken into account in the data syntheses to make fairer interpretations of the instrument's validity.

**Table 1. Ratings for validity evaluation**

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<td>Strong</td>
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<td>++ (-)</td>
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<tr>
<td>+ (-)</td>
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<td>+/-</td>
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<tr>
<td>?</td>
<td>Only studies of poor methodological quality</td>
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Results

Systematic search
The systematic search yielded 271 studies (Figure 2). After removal of duplicates (n=49) and the exclusion of studies based on title and abstract (n=179), full-text articles of 43 studies were assessed with regard to eligibility. Of the 43 studies retrieved, 21 were excluded. The main reason for exclusion was that the study did not concern talent development (n=16). Other reasons were the inclusion of adult players only (n=1) and the study concerned the predictive value of junior competition results or ranking with regard to adult success without information on personal talent determinants (n=2), or factors beyond the player i.e. environmental involvement (n=2). A reference check on the remaining 22 studies yielded 11 additional studies of which three were excluded. Two studies were excluded because they did not focus on talent development (n=1) or young players (n=1). A third study was excluded because it was a Spanish copy of an article included. Finally, 30 studies were included which investigated aspects of talent development in young racquet sport players covering tennis (n=23), table tennis (n=5) and badminton (n=2). No studies meeting the inclusion criteria were found with regard to squash. The studies included were based on a cross-sectional (n=27) or a (multi-cohort) longitudinal design (n=3). Twenty-nine articles were written in English and one in French. Detailed information of each study included is presented in Online Resource 2.

Quality check
The results of the overall quality check using the critical review form for quantitative studies by Law et al. (1998) are summarised in Table 2. Nine studies were rated ≤ 50%, 15 studies between 51% and 75%, and 6 studies >75%, and were evaluated as studies with low, good and excellent methodological quality, respectively. The differences among the qualities of the studies were especially observed with regard to the inclusion of relevant background literature, the ethical issues, the description of the reliability of instruments used, the conclusion, the implications and the study’s limitations. Six of the 30 articles reported detailed information about the reliability of the measurements.

Classification using the DMGT 2.0
The classification of the instruments extracted from the included articles using the natural ability and intrapersonal catalyst domains of the DMGT 2.0 (Gagné, 2010) is shown in Figures 3 and 4. The instruments cover a large area of the natural abilities (Figure 3) and intrapersonal catalysts (Figure 4). Especially the physical aspects of both concepts include a large number of various instruments. The creative and social aspects of the natural abilities and volition as catalysts are not specifically assessed in any instrument.
Figure 2. Flow chart systematic search
### Table 2. Results of the quality check using the Critical Review Form – Quantitative Studies (Law et al., 1998)

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**Notes:** *only the first author is mentioned; NA: not applicable; ?: indeterminate rating; 1=Was the study purpose stated clearly? 2=Was relevant background literature reviewed? 3=Was the design appropriate for the research question? 4=Was the sample described in detail? 5=Was sample size justified? 6=Was informed consent obtained? (if not described, assume no) 7=Were the outcome measures reliable? (if not described, assume no) 8=Were the outcome measures valid? (if not described, assume no) 9=Was intervention described in detail? 10=Were results reported in terms of statistical significance? 11=Were the analysis methods appropriate? 12=Was clinical importance reported? 13=Were any drop-outs reported? 14=Were conclusions appropriate given the study methods? 15=Are there any implications for clinical practice given the results of the study? 16=Were limitations of the study acknowledged and described by the authors? * item was not applicable because only descriptive characteristics were presented.
Figure 3. Overview instruments ‘natural abilities’

ASSESSING PERSONAL TALENT DETERMINANTS

NATURAL ABILITIES

Mental

Muscular

Social*

Creative*

Perceptual

Intellectual

Speed

Endurance

Power

Strength

Flexibility

5m run11,15;
10m run15,28;
20m run12,13,15,23;
40m run23;
20 yard dash7,25,26;
Running speed16

VO2max – labora-
torium test10,16,19;
Wingate anaerobic
test4,30;
Cooper test30;
Bleep test (20m
shuttle run test)28;
Muscle
endurance test28;
2400m running
test10,11,13,23;
1.5 mile run25;
PWC170 – physical
exercise capacity7

Lower extremities:
Vertical
jump2,19,24,25,26,28;
Counter
movement jump4,15;
Modified Sargent
jump2,23;
Squat jumps4,15;
Quarter jump1,12,13,23;
Multi-rebound jump15;
Pump & squat19;
Drop
jump (0.2m; 0.3m;
0.4m)4,15;
Lateral jump;
Standing long jump;
Preferred leg hop2

Upper extremities:
Medicine ball put /
throw1,11,12,13,23,28;
Medicine ball toss –
forehand and
backhand26;
Medicine ball toss –
overhead and reverse
overhead24,28

Oblique sit-ups
60s11,12,13,23,26;
7-level
abdominal strength
test28;
Bent knee
sit-ups2;
Lower
back2,28;
Leg extension2,7,28;
Push-ups 30s /
60s2,24,25,26;
Shoulder extension26;
Plantar flexors15;
Elbow extension4;
Elbow flexion4;
Hand grip2,7,19,24,25,26,28

Game understanding test
(basic; advanced A3;
advanced A8)2;
Anticipatory
skills test6;
Vienna
determination
unit20

Sit and reach
test2,7,24,25,26;
Trunk extension/
flexion2,19;
Forward bend on
the bench11,12,23;
Hamstrings26,28;
Launge23;
Shoulder
rotation26;
Shoulder flexion-
extension28;
Twist with the
stick12,23;
Hips12

504489-L-sub01-bw-Faber504489-L-sub01-bw-Faber504489-L-sub01-bw-Faber504489-L-sub01-bw-Faber
FIGURE 4. Overview instruments 'intrapersonal catalysts'

**ASSESSING PERSONAL TALENT DETERMINANTS**

## INTRAPERSONAL CATALYSTS

### Traits

- **Mental**
  - Rosenberg’s Self Esteem Scale\(^{18}\)
  - Self-efficacy test\(^{18}\)

- **Physical**
  - Anthropometry\(^{1,6,7,11,19,21,22,26,29,30}\)
  - Body composition\(^{1,6,7,16,19,21,22,23,26,29,30}\)
  - Respiratory function\(^7\)

### Body Composition
- Weight\(^2\)
- Height\(^2\)
- Sitting height
- Somatotype
- Biological Maturation Information Questionnaire (BMIQ)\(^{28,29}\)

#### Lengths:
- Trochanter – tibial
- Acromial – radial
- Radial – styloid
- Hand, Leg, Arm, Arm span
- Trochanter-box

#### Breadths:
- Bi-crystal
- Bi-acromial
- Bi-condylar width femur
- Bi-condylar width humerus
- Hand, Ankle

#### Girths:
- Thigh, Calf, Ankle, Chest, Arm, Forearm
- Wrist, Gluteal, Neck, Head

### Body Mass Index (BMI), Body density, Bone mass(\%), Muscle mass(\%), Fat mass(\%), Fat free mass(\%)

#### Skinfolds:
- Chest, Mid-abdominal, Supra-scapular, Supra-iliac, Thigh, Calf, Sub-scapular, Biceps, Triceps

### Forced Vital Capacity (FVC), Forced Expiratory Volume – first second (FEV1)
Validity evaluation

The data of the specific methodological quality check for validity using Box F ‘hypothesis testing’ of the COSMIN checklist are presented in the Online Resource 3. The data synthesis for the validity evaluation of the instruments for talent development found in this review is summarised in Table 3. A more detailed data synthesis is presented below by means of four subsections, which are derived from the DMGT 2.0 (Figure 1): mental natural abilities, physical natural abilities, intrapersonal traits and intrapersonal goal management (Gagné, 2010).

Mental natural abilities

Six studies focused on mental natural abilities, including one study on a multi-cohort longitudinal design (Panjan, Sarabon, & Filipčič, 2010) and five studies based on a cross-sectional design (Bańkosz, 2012; Blomqvist, Luhtanen, Laakso, & Keskinen, 2000; Farrow & Reid, 2012; Mantis, Zachopoulou, & Mavridis, 1998; Roetert, Garrett, Brown, & Camaione, 1992). The methodological quality evaluation for validity yielded a rating of good for the multi-cohort study (Panjan et al., 2010) and fair for three cross-sectional studies (Blomqvist et al.,2000; Mantis et al., 1998; Roetert et al., 1992) (Online Resource 3). Two cross-sectional studies (Bańkosz, 2012; Farrow & Reid, 2012) were rated poor due to small sample size (n<30) (Mokkink et al., 2010).

Blomqvist et al. (2000) and Farrow & Reid (2012) included complex tasks for game understanding and anticipatory skills tests, respectively, which appealed to higher cognitive functions considerably. Bańkosz (2012), Panjan et al. (2010) and Roetert et al. (1992) used simpler perceptual tasks. Mantis et al. (1998) included both complex and simple mental tasks. There is limited evidence that more complex mental tasks can be used for talent developmental purposes to distinguish elite from non-elite players and to give direction to training in table tennis, badminton and tennis, respectively (Bańkosz, 2012; Blomqvist et al.,2000; Mantis et al., 1998). Because the methodological quality of the study of Blomqvist et al. (2000) and Mantis et al. (1998) was rated as fair, the validity of the game understanding test and the Vienna determination unit was rated as positive based on limited evidence (+). Kinaesthetic differentiation ability measurements were only evaluated in one study of poor methodological quality (Bańkosz, 2012), so the validity for talent development was rated as unknown (?). Additionally, Mantis et al. (1998) demonstrated the added value of their simple perceptual tasks to predict current performance of the tennis serve (+). Panjan et al.’s (2010) longitudinal and Roetert et al.’s (1992) cross-sectional study, on the other hand, did not confirm simple reaction time as an important factor for (future) tennis performance and the response time and reaction pole were rated negative correspondingly based on limited (-) and moderate evidence (–). From all six studies, only two studies presented acceptable information on reliability (Table 2) (Blomqvist et al.,2000; Farrow & Reid, 2012).
**Physical natural abilities**

In total, 20 studies focused on physical natural abilities, including 18 studies based on a cross-sectional design and 2 studies on a (multi-cohort) longitudinal design. The methodological quality evaluation for validity yielded good (n=1) (Panjan et al., 2010), fair (n=10) (Faber, Oosterveld, & Nijhuis-Van der Sanden, 2014; Filipčič & Završki, 2002; Filipčič & Filipčič, 2005a; Filipčič & Filipčič, 2005b; Filipčič, Pisk, & Filipčič, 2010; Leone & Larivièere, 1998; Mantis et al., 1998; Nikolić, Furjan-Mandić, Kondrič, 2014; Roetert et al., 1992; Roetert, Brown, Piorkowski, & Woods, 1996), to poor (n=9) (Amusa, Toriola, & Dhaliwal, 2002; Bencke et al., 2002; Elliott, Ackland, Blanksby, & Bloomfield, 1990; Girard & Millet, 2009; Karnia et al., 2010; Landlinger, Stöggl, Lindinger, Wagner, & Müller, 2012; Roetert, Piorkowski, Woods, & Brown, 1995; Van den Berg, Coetzee, & Pienaar, 2006; Ziemann, Sledziewska, Grywacz, Gibson, & Wierzb, 2011) ratings. Most instruments found for measuring physical natural abilities were rated from negative based on moderate evidence (−) to conflicting findings (+/−). No evidence was found in this review to confirm the usefulness of these instruments in talent development in racquet sports except for the assessment of coordination (++ and sport-specific tasks (+) (Table 3).

Although speed, endurance, flexibility, agility, speed and balance seem to be related to performance at some age (Filipčič & Filipčič, 2005a; Filipčič & Filipčič, 2005b; Filipčič et al., 2010; Leone & Larivièere, 1998; Nikolić et al., 2014; Roetert et al., 1996, Van den Berg et al., 2006; Ziemann et al., 2011), these findings cannot be generalised to other studies recruiting other age groups and/or other playing levels because no longitudinal studies are available. Moreover, Panjan et al.’s multi-cohort longitudinal study (2010) found that a sport-specific test (‘racquet ball handling’) and two agility tests (‘9 x 6m run’ and ‘fandril’) were the most promising variables for predicting which players belonged to the elite or non-elite group, but the accuracies of the predicted models were poor with high relative errors. Only Girard & Millet (2009) included information on reliability of their measurements.

Yet, Mantis et al. (1998), Faber et al. (2014) and Nikolić et al. (2014) demonstrated that eye-hand coordination is an essential ability for high performance in table tennis and tennis, which legitimates the instruments used for talent development. Three studies support these findings by showing that their sport-specific tests ‘rebouncing tennis ball with racquet’ and ‘race ball handling’, in which eye-hand coordination is an essential feature, have significant relation with competition outcomes in adolescent tennis players (Filipčič & Filipčič, 2005b; Filipčič et al., 2010; Panjan et al., 2010). The methodological quality regarding the validity aspects of these studies was rated good (Panjan et al., 2010) or fair due to the small sample (Faber et al., 2014; Mantis et al., 1998) or due to the absence of prior hypotheses (Filipčič & Filipčič, 2005b; Filipčič et al., 2010; Nikolić et al., 2014). Consequently, the level of evidence for an eye-hand coordination test is positive based on moderate evidence (++). Reliability aspects were only part of the study of Faber et al. (2014) and were considered sufficient for the test used in this study.
Table 3. Summary of the validity evaluation of instruments for talent development

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# Elite players included: elite players, expert players, high-performance players and national players; non-elite players included: non-elite players, competitive and non-competitive players.
The specific stroke tasks (e.g. forehand or backhand stroke) seem to have a significant relation with performance results in tennis at that time (Landlinger et al., 2012; Roetert et al., 1992). However, these relations are quite logical as such tasks are part of regular training and/or matches and might not be good indicators for measuring physical natural abilities.

**Intrapersonal traits**

Anthropometry and body composition measurements were used in 14 studies including 1 multi-cohort longitudinal study and 13 cross-sectional studies. The methodological quality regarding the validity of the multi-cohort study (Panjan et al., 2010) was rated good and of the cross-sectional studies poor (n=10) (Amusa, Toriola, Dhaliwal, & Mokgwathi, 2001; Bencke et al., 2002; Carrasco, Pradas, & Martinez, 2010; Elliott et al., 1990; Karnia et al., 2010; Munivran, Paušić, & Kondrič, 2011; Sánchez-Muñoz, Sanz, & Zabala, 2007; Van den Berg et al., 2006; Van den Berg, Coetze, & Pienaar, 2012; Ziemann et al., 2011) to fair (n=3) (Filipčič & Filipčič, 2005b; Leone & Lariviere, 1998; Nikolić et al., 2014). These included studies of fair or good quality show conflicting findings regarding their validity for talent development (+/-).

Leone & Lariviere (1998) conclude that already in adolescence clear anthropometric differences (body mass, height and the sum of six skinfolds) exist between elite athletes from gymnasts, cyclists and tennis players. They suggest that this could be a starting point for talent detection or identification and training adjustment. Filipčič & Filipčič (2005a) confirm these findings with respect to body mass and skinfolds, and add calf girth as a significant variable for predicting competition success in tennis. Nikolić et al. (2014) concluded that also subcutaneous abdomen fatty tissue positively influences a ball control task in young table tennis players. In line with these studies, Panjan et al. (2010) showed that coaches selected body height as one of the most important morphological characteristics for good tennis players. However, the automatic methods of this study to model future performance did not confirm the predictive value of the anthropometric and body composition measurements. Moreover, the studies of poor quality do not add new insights to the above findings and only contribute by supplying knowledge regarding subgroups of elite athletes at a certain age. The reliability of the instruments used was not described in any of these studies.

Only Elliot et al. (1990) included instruments measuring respiratory functions in their longitudinal study. They found no differences between elite and non-elite players in lung volume or air flow rate. However, because the methodological validity quality of Elliot's study was rated as poor (Online Resource 3), the predictive value of these instruments was rated as unknown (?).

Lane, Jones, and Stevens (2002) used Rosenberg's Self-Esteem Score, Self-efficacy scale and the Modified COPE (MCOPE) to analyse the psychological state of a tennis player. The authors conclude that low self-esteem significantly reduced self-efficacy and was associated with maladative coping strategies. Consequently, the validity of Rosenberg's Self-Esteem Score and Self-efficacy scale was rated as positive based on
moderate evidence (++). Lane et al. (2002) also confirmed reliability and other validity aspects from those related to talent development of both instruments in the ‘Methods’ section (Table 2).

**Intrapersonal goal management**

Finally, instruments to measure the intrapersonal catalysts concerning mental and goal management issues were presented in two studies of good methodological validity. Gillet, Berjot, and Gobancé (2009) confirmed the predictive value of instruments to assess motivational aspects in young tennis players. They revealed that self-determined motivation towards tennis, measured with the Sport Motivation Scale, significantly predicted sport performance during 2 years in adolescent players (13-14 years) among the top 150 in France. Self-determined motivation is described along a continuum of intrinsic motivation, extrinsic motivation and amotivation, in which being involved and engaged in a freely chosen activity for pleasure and satisfaction are important aspects. Moreover, the perceptions of autonomy, competence and relatedness as measured with the Basic Psychological Needs in Sport Scale were suggested to indirectly predict performance during a season by a positive influence on self-determined motivation. The validity of the Sport Motivation Scale and the Basic Psychological Needs in Sport Scale was rated as positive based on moderate evidence (++). In addition, the authors note that the coefficients in their model are small, and many other factors may contribute to sport performance. Gillet et al. (2009) provided additional evidence for both instruments, in which reliability and the aspects of validity, other than those related to talent development, were confirmed.

Low self-esteem was, as previously described, related to maladaptive coping strategies in tennis (Lane et al., 2002). Interventions to optimise self-efficacy should focus on utilisation of adaptive coping strategies, especially among young tennis players with low self-esteem. Consequently, the validity of the MCOPE was rated positive based on moderate evidence (+++) with regard to the directions for talent development. Lane et al. (2002) confirmed reliability and other validity aspects of the MCOPE in the ‘Methods’ section.

**Discussion**

The results of this review provide an overview of all instruments identified by conducting a systematic search for talent development in racquet sports. Classifying these instruments by DMGT 2.0 (Gagné, 2010) reveals that most instruments are developed to measure physical aspects, which is in accordance with a part of the proposed essential characteristics of elite racquet players (Abernethy, 1991; Ak & Koçak, 2010; Banzer et al., 2008; Chin et al., 1995; Hjelm et al., 2012; Kovacs, 2007; Lees, 2003). However, mental, social and self-regulation aspects are also considered essential features (Chu et al., 2012; Jonker, Elferink-Gemser, & Visscher, 2010; Lees, 2003; Liu et al., 2012; Lopez & Santelices, 2012; Lubbers, 2006). Only a few instruments focus on the assessment of a player’s intellectual or perceptual mental natural abilities, mental intrapersonal catalysts or goal-management
abilities (Blomqvist et al., 2000; Lane et al., 2002; Mantis et al., 1998; Panjan et al., 2010; Roetert et al., 1992). The mental domains ‘creativity’ and ‘social’ and the goal management aspect of ‘volition’ were not covered by any instrument (Figure 2 and 3).

To assess a player’s potential, multidimensional characteristics should be taken into account (Elferink-Gemser et al., 2011; Gagné, 2010) and a combination of instruments measuring aspects in all domains of the DMGT 2.0 may be more appropriate. The DMGT 2.0 of Gagné (2010) (Figure 1) suggests a pathway for talent development and can serve as a guideline for those involved. However, it does not give a specific content for tests for talent development in a certain field. It is up to the players, parents, trainers, coaches, politicians and scientists to fill the model with specific qualities to optimise the development process for each specific sport. At this moment, the model only contains factors assumed to be important in talent development. Only a well-developed database will allow us to test the DMGT 2.0 with regard to its validity. When essential talent determinants are identified, adequate tests to measure these features need to be searched or developed, and tested with regard to their validity for talent development in longitudinal studies. To our knowledge, this review presents a first attempt at evaluating instruments to assess talent determinants in racquet sports.

The validity evaluation of the instruments found in this review was fairly complex. No strong evidence was available to confirm or reject the validity of any of the instruments identified due to the methodological quality of the included studies, and only six studies included information regarding the aspects of reliability of their instruments (Table 2). Additionally, the studies used different designs and included specific samples, which complicated the comparison of studies using similar instruments. Finally, there was a lack of longitudinal studies to test the predictive value of the instruments. With the DMGT 2.0 in mind, it is suggested that all sports, including racquet sports, need instruments to measure multidimensional characteristics for talent development in which fine-tuning to the context is possible (Elferink-Gemser et al., 2011; Unierzyski, 2006). For example, eye-hand coordination is considered to be essential for all racquet sports, but how this can be assessed is different for each sport, boys and girls, and a player’s development.

It becomes evident from the data synthesis that the instruments classified among intellectual and perceptual natural abilities could be useful for talent development (Blomqvist et al., 2000; Mantis et al., 1998), except for perceptual tasks in which simple reaction time was assessed (Panjan et al., 2010; Roetert et al., 1992). However, the studies regarding reaction time were both conducted in young tennis players in whom reaction time possibly is no crucial factor in that period of their developmental phase for differentiating between high and low performers. Moreover, reaction time could be essential in elite tennis, table tennis, badminton and squash due to the high game speed in these sports (Lenoir et al., 2000). For that reason, the assessment of reaction time for talent development is not instantly disqualified by this result and can be measured in a laboratorial setting or in a sport-related context.

Additionally, classifying the instruments suggested to assess intellectual or perceptual natural abilities was rather complex due to the differences in terminology in cognitive
assessing personal talent determinants (Chan, Shum, Toulopoulou, & Chen, 2008). The decision was made to classify instruments on the basis of more complex tasks that required higher-level cognition processes as intellectual tests, and the more simple tasks as perceptual tests. The instrument’s description in the original article was used as a guideline for classification. As a result, the intellectual domain is covered by a game understanding test, an anticipatory skills test and a complex multi-limb coordination task. Probably the addition of the assessment of other higher-level cognitive function, i.e. executive functions, could enrich a talent programme. Executive functions concern a player’s capacity to inhibit responses, to adapt quickly and to change strategies to find new creative solutions (Anderson, 2002; Strauss, Sherman, & Spreen, 2006). Excellent processing already proved to be a talent predictor in soccer (Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012) and could probably also be a strong predictor for a racquet player’s potential.

A lot of conflicting findings were observed with regard to the physical instruments. As mentioned above, this might be due to the differences in designs and samples (Online Resource 2). In addition, classifying the instruments measuring the physical natural abilities was complicated because of the multidimensionality of the measurements. Like for the mental natural abilities, instruments were classified on the factor that was stressed most during the measurement. Moreover, authors assessing the same construct used different instruments, which troubles comparability. It seems that in cross-sectional studies in which elite racquet players are compared to non-elite players or to elites from other sports, differences exist in physical appearance i.e. personal characteristics and physical performance (Faber et al., 2014; Filipčić & Filipčić, 2005a; Filipčić & Filipčić, 2005b; Filipčić et al., 2010; Girard & Millet, 2009; Leone & Lariviere, 1998; Mantis et al., 1998; Nikolić et al., 2014; Roetert et al., 1996; Van den Berg et al., 2006; Ziemann et al., 2011). The longitudinal study of Panjan et al. (2010), however, is not able to confirm a moderate or strong predictive value for tennis players. At this moment, it seems that only the physical development of elite players per phase with respect to appearance, muscular and motor performance can be evaluated. Fitting this profile probably ensures young players a high ranking in that phase, but it will not guarantee later success in racquet sports. It is still unknown at what time a player needs to fit a certain profile to become a world class athlete. Differences in growth, development and maturation interfere with test results and impede an adequate interpretation (Malina et al., 2005; Silva et al., 2010). Probably controlling for these inter-individual differences using maturity indicators, e.g. body proportionality (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002), will provide more valid results.

The instruments used for assessing mental and goal management intrapersonal catalysts appear to be important for talent development. Motivation and self-esteem and associated mental aspects have been shown to be associated to success in tennis and are considered important for realising optimal performance (Gillet et al., 2009; Lane et al., 2002). Talent development programmes should probably do well by including such assessments and related interventions to improve the talent development process of young racquet players. Ignoring these aspects will possibly waste high-potential players by disrupting optimal learning and developmental curves.
Finally, some limitations of this review must be acknowledged. First, a rather disbalanced distribution of articles was included in this review with respect to the four racquet sports: 23 articles focused on tennis, 5 on table tennis, 2 on badminton and none on squash. As a consequence, the results of this review are especially valid for talent development in young tennis players. Generalisation to the other racquet sport is probably possible due to the similarities mentioned earlier (Lees, 2003), but should be made with caution. Secondly, biological maturation, and development and learning curves influence all test outcomes of young players. These aspects need careful consideration since they systematically pressure the instruments’ validity for talent developmental purposes (Elferink-Gemser et al., 2011; Philips et al., 2010). When norm values are developed, it must be evaluated which maturation characteristics should be taken into account. Thirdly, some studies were rated poor based on the sample size (n<30) using the criteria of the COSMIN-checklist (Mokkink et al., 2010). These criteria reduce misinterpretations based on type II errors and on the lack of generalisation possibilities. Nevertheless, small samples may include a large part of the target population when studies are conducted in a relative small country focusing on elite players. Finally, the systematic search was only conducted in the established databases for quality reasons. Although a reference check was carried out, it is unclear to what extent a publication bias exists. A distortion could occur if only positive results are published in scientific journals, or that relevant studies were missed because they are not indexed in the databases used. In addition, perhaps valid instruments are available in practice, but no scientific studies were carried out to verify their predictive value.

In this first comprehensive review regarding the assessment of personal talent determinants in racquet sports, instruments were found for measuring the multidimensional characteristics of the physical and mental domain for both natural abilities and intrapersonal catalysts. The complex validity analysis yielded an ambiguous endpoint. It appeared that the value of using instruments in this perspective largely depends on the context and developmental phase in which they are used. It seems that a lot of physical outcomes determine a player’s capacity at that specific moment or phase, but that predicting is more difficult when using such parameters in combination with the lack of longitudinal studies. Mental and goal management catalysts could be essential predictors for future performance, but may be useless if a player does not have the physical potential to become an elite player.

Future research should focus on the identification of multidimensional talent determinants, the development of adequate instruments and their predictive value in longitudinal designs. Specific attention is needed with regard to talent determinants in different phases in talent development and with regard to the evaluation of the instrument’s predictive value for the next development phase (Unierzyński, 2006). The instruments assessing intellectual and perceptual natural abilities, mental traits and goal management have good prospects for the use in a talent development programme, but must be investigated in all sports in a longitudinal study including a follow-up period of at least 10-15 years. Moreover, the pre-
predictive value of the instruments assessing physical aspects in racquet sports should be evaluated in such a long-term study, given that at this moment only two studies are available (Elliot et al., 1990; Panjan et al., 2010). Longitudinal research might benefit from the inclusion of differentiations per phase of development and multiple periodic monitoring. An assessment closer to the moment in which performance must be predicted, while taken into account the interference of growth and maturation, probably yields a higher predictive value. Furthermore, assessments of other complex cognitive functions (e.g. executive functions), creativity, social skills and volition must be found or developed. Also research on the transferability of the instruments between sports seems logical, especially for the instruments measuring the less sport-specific like motivation or self-efficacy. Experience and perspectives from elite players and their trainers / coaches investigated in a qualitative approach can reveal new insights in talent determinants. Finally, reproducibility results of the instruments collected in the target population are essential to make a fair interpretation possible. Perhaps, making evidence-based choices in selecting players based on their potential is possible in that case.

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Supplemental data

Online Rescource:
1. Search strategy per database.
2. Detailed information included studies.
3. Results of the quality check using the COSMIN-checklist.

References


Chapter 3


Chapter 4

Can an early perceptuo-motor skills assessment predict future performance in youth table tennis players?
An observational study (1998-2013)

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Abstract

This study intended to investigate the capability of the four test items “sprint”, “agility”, “speed while dribbling” and “throwing a ball” of the Dutch perceptuo-motor skills assessment used at the age of 7-10 years to predict table tennis performance (U13, U15 and U18) in an observational study. Data of 1191 young table tennis players, collected from 1998 to 2013, were analysed in univariable and multivariable logistic and linear regression models. The test items “sprint”, and “throwing a ball” showed to be significant predictors for table tennis performance outcomes in boys (p<0.05). For girls, besides these test items also “speed while dribbling” had a significant contribution (p<0.05). Since the accuracies of the models were low, it is advised to include other determinants to enhance the predictive value of a model for table tennis performance. Nevertheless, it can be concluded that a perceptuo-motor skills assessment might improve the effectiveness of talent programmes in table tennis as an additional method to objectively estimate a youth players’ potential. Future research focusing on the inclusion of test items specifically assessing eye hand coordination and other domains, for example, the psychological and the environmental domain, related to table tennis performance are recommended.

Keywords: psychomotor performance, aptitude, racquet sports, gifted children, predictability
Introduction

The development from a youngster to an elite world-class player in a large number of sport games is a long-term, multidimensional and highly complex process (Elferink-Gemser, Jorde, Coelho-E-Silva, & Visscher, 2011; Phillips, Davids, Renshaw, & Portus, 2010; Panjan, Sarabon, & Filipčič, 2010). This also applies to the development of youngsters in table tennis to elite players. As in many other sports, these youngsters need to develop tremendously in the fields of playing techniques, tactics, physical fitness and not in the least in the mental and psychological domain for reaching the world’s highest playing level (Ak & Koçak, 2010; Akpinar, Devrilmmez, & Kirazci, 2012; Chu, Chen, Chen, Huang, & Hung, 2012; Horsch, 1990; Kondrič, Zagatto, & Sekulić, 2013; Lees, 2003; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Raab, Masters, & Maxwell, 2005). The associations’ talent programmes try to support young table tennis players aiming for the elite level by setting up special training facilities and personal coaching. Players with the highest potential for elite table tennis are sought to ensure the effectiveness of such programmes (Gagné, 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). However, the identification and selection of these rough diamonds is a challenge as measuring the potential for elite table tennis is still a wasteland (Faber, Bustin, Oosterveld, Elferink-Gemser, & Nijhuis-Van Der Sanden, 2016).

Table tennis is regarded as an early entry sport and associations already try to find high potential players at a young age (< 10 years) (Limoochi, 2006). This is because the difficult technical skills of table tennis are supposed to be learned best at a young age, i.e. age from approximately 5 till the pubertal growth spurt (12–14 years) (Stang & Story, 2005), using the most sensitive period for learning perceptuo-motor skills (Knudsen, 2004; Watanabe, Savion-Lemieux, & Penhune, 2007). Table tennis is a technically and tactically complex sport, with a huge range of different technical variations and tactical implications of each of basic strokes (Munivrana, Furjan-Mandić, & Kondrič, 2015; Munivrana, Petrinović, & Kondrič, 2015) that, like in other complex sport games, the optimal automation of technical skills also entails better possibilities for a player to execute tactical strategies (Kannekens, Elferink-Gemser, & Visscher, 2011). However, at such a young age table tennis performance itself is influenced by individual differences in growth, maturation, development and learning curves, training experiences, competition participation and environmental factors. These factors can create temporary advantages or disadvantages at a certain point in time, but probably do not reflect a player’s full potential (Brouwers, De Bosscher, & Sotiriadou, 2012; Malina, Cummings, Morano, Barron, & Miller, 2005; Reid, Crespo, Santilli, Miley, & Dimmock, 2007; Silva et al., 2010). Consequently, selection solely based on table tennis performance results are considered inadequate at a young age and trainers are in search of additional ways to be able to make a better estimate of a youth player’s potential for elite table tennis and to enhance the success rate of talent programmes.

Since 1998, the Netherlands Table Tennis Association uses a perceptuo-motor skills assessment as part of their talent programme to assess youth players (7-10 years) on their potential for table tennis with regard to the perceptuo-motor domain. This assessment was
set up by professional trainers with expertise in talent identification. Authentic table tennis tasks were avoided during the assessment, because untrained tasks are considered to better reflect future potential than specific sport skills themselves at this age (Gagné, 2004; Morrow, Jackson, Disch, & Mood, 2011; Vaeyens et al., 2008). Although the composition of the assessment changed over time (Faber, Elferink-Gemser, Oosterveld, & Nijhuis-Van Der Sanden, 2014; Faber, Nijhuis-Van Der Sanden, Elferink-Gemser, & Oosterveld, 2015; Faber, Oosterveld, & Nijhuis-Van Der Sanden, 2014), the four test items “sprint”, “agility”, “speed while dribbling” and “throwing a ball” were included from 1998 till today (Table 1). These items together intend to measure speed, coordination of (simultaneous) foot and arm movements, dynamic balance, combined gross and fine perceptuo-motor skills, accuracy, agility, ball control and arm velocity (German Table Tennis Association, 2008). These skills are considered fundamental in developing outstanding technical qualities specific to table tennis (German Table Tennis Association, 2008; Horsch, 1990; Limoochi, 2006). As such, including these items in an assessment of perceptuo-motor skills for youth players (age 7-10) as part of a talent programme seems sensible (di Cagno et al., 2014; Girard & Millet, 2009; Limoochi, 2006; Pion et al., 2015; Vandorpe et al., 2012).

Table 1. Characteristics of the perceptuo-motor skills test items assessment of the Netherlands Table Tennis Association (Netherlands Table Tennis Association, 1998)

<table>
<thead>
<tr>
<th>TEST ITEM</th>
<th>ASSESSING</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>Sprint (s)</td>
<td>The ability for quick accelerations and turns (footwork) in combination with a manual task.</td>
<td>‘Sprint’ included a pyramid-shaped circuit (isosceles triangle, basis 6 m, height 5 m) in which players needed to gather and return 5 table tennis balls one by one from the starting point as fast as possible. The test included 1 attempt.</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>The ability to quickly coordinate gross arm and leg movements simultaneously while reasonable strength of the upper and lower extremities is required.</td>
<td>For ‘agility’, players needed to alternately climb over a gymnastics’ cabinet (5 times) and under and over a low hurdle (4 times) as fast as possible. The test included 1 attempt.</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>The ability to control a ball (eye-hand coordination and fine motor / ball control) during a dynamic task, sideward zigzagging (footwork).</td>
<td>‘Speed while dribbling’ used a zigzag circuit in which the players needed to move sideways as fast as possible while dribbling one-handed with a basketball. The test included one attempt.</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>The ability to combine the coordination of an arm movement with high arm velocity (combination gross and fine motor skills).</td>
<td>At ‘throwing a ball’ players were instructed to throw a table tennis ball as far away as possible with the arm of their preference. The best of 3 attempts was recorded in metres (m).</td>
</tr>
</tbody>
</table>
The inclusion of the test items “sprint”, “agility”, “speed while dribbling” and “throwing a ball” from 1998 till the present, provides the opportunity to evaluate their predictive validity for future table tennis performance, which is essential for talent developmental purposes (Gagné, 2004; Vaeyens et al., 2008). At this moment, there is a lack of prospective studies investigating predictive indicators for future performance in racquet sports (Faber et al., 2016). This study is, to our knowledge, one of the first attempts to fill this gap by examining the capability of the perceptuo-motor test items to predict future table tennis performance. As a result, this study focuses on the following research question: Can the perceptuo-motor test item scores at a young age (U11; age 7-10) predict future performance in youth table tennis players (U13, U15 and U18)?

It is hypothesised that the outcomes of the test items of the perceptuo-motor skills assessment significantly predict future performance in youth table tennis players. We realise that the perceptuo-motor potential is only one factor in a multidimensional and complex process (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Philips et al., 2010; Reilly, Williams, Nevill, & Franks, 2000) and other factors like motivation, the influence of parents, the presence of local training facilities and coaches, and the availability and level of team members are also relevant (Gillet, Berjot, & Gobancé, 2009; Lane, Jones, & Stevens, 2002; McCullagh et al., 1993). So, it is not likely to find a high-accuracy model. Nevertheless, the results of this study will improve the insight if a perceptuo-motor assessment should be part of assessing the potential in youth table tennis players.


Materials & methods

Ethics statement

This study was conducted in full compliance with the declaration of Helsinki. The data of this study are open to the public and made available by the Netherlands Table Tennis Association from their archives of published records of the national talent days (1998-2012), youth national rankings (1999-2013) and competition results (1999-2013). All data were recorded in an anonymous data set.

Design

This study used an observational design to evaluate the predictive validity of four perceptuo-motor test items for table tennis performance. Youth table tennis players were assessed with regard to their perceptuo-motor skills between the ages of 7 and 10 (U11) at the annual national talent day in the period of 1998-2012. If players attended more than once at the national talent day, only the last test outcomes were included in this study. The spring season’s performance outcomes, i.e. youth national tournament license and competition score, of these players were recorded every year following the assessment (1999-2013).
Players
This study included all youth players participating at one (or more) annual national talent
days of the Netherlands Table Tennis Association between 1998 and 2012. The players
of the national talent day were selected every year by the regional technical staff (i.e. trai-
ners and coaches) to represent their regional competition department. The Netherlands
have eight regional competition departments. The regional technical staff was instructed
to send the youth members of a table tennis club associated with the Netherlands Table
Tennis Association in their region (a maximum of 8 boys and 8 girls), with highest potential
for elite table tennis regarding both physical and mental aspects. These players needed to
be aged between 7 and 10. No further explicit inclusion criteria were provided.

Perceptuo-motor test items
All youth players were assessed under similar conditions at the national sport centre during
the national talent day on the basis of the four test items, “sprint”, “agility”, “speed while
dribbling” and “throwing a ball” of the perceptuo-motor skills assessment. Before starting
the assessments, all participants did a warming-up. Protocols captured the standardisati-
on of the test items by including a detailed description for materials, set-up, assignment,
demonstration, testing-phase and registering test scores (Netherlands Table Tennis Asso-
ciation, 1998). “Sprint” included a pyramid-shaped circuit in which players need to gather
and return five table tennis balls one by one as fast as possible from five different bas-
kets starting at the basis of the pyramid-shaped circuit. For “agility”, players needed to get
through a circuit, including climbing over a gymnastics’ cabinet (five times) and under and
over a low hurdle (four times), as fast as possible. “Speed while dribbling” used a zigzag
circuit in which the players needed to move sideways as fast as possible while dribbling
with a basketball using one hand. “Sprint”, “agility” and “speed while dribbling” all included
one attempt in which time was measured in seconds. At “throwing a ball”, the players threw
a table tennis ball as far away as possible with their preferred hand. The distance from the
starting-point at the marked line to the point of the ball’s first bounce was measured in
meters. The best of three attempts was used as final score. Short descriptions of the test
items are also presented in Table 1. The testers were table tennis trainers or students of
physiotherapy, who were trained to guarantee that the test protocols were used in a stan-
dardised way; they were familiarised with the test protocol and instructions and feedback
were given during a training session by an expert-trainer of the Netherlands Table Tennis
Association. A reproducibility study using a test-retest design in a subsample of the sam-
ple of the current study, showed acceptable intraclass correlation coefficients ranging from
0.79-0.88 (p<0.01) with coefficients of variation between 3-6% (Faber et al., 2015).

Table tennis performance
In the Netherlands, youth players can participate in the official tournaments and compe-
tition of the Netherlands Table Tennis Association. Tournaments are played individually
and generally use a knock-out system in which only the match-winner continues to the
next round till the finals are played. The official tournaments use a hierarchical structure
and are only open to players of a certain playing level i.e. the national tournament licence.
The national tournament license depends on the player’s table tennis performance; both the participation and the results in competition and tournaments yield points (Netherlands Table Tennis Association, 2013b). The highest youth national tournament license is an A-licence and the lowest a D-licence. Novice players start with a D-licence and depending on their score, they can promote to a higher licence.

Competition is played with a club-team consisting of at least three players. The competition uses a hierarchical structure including both the national leagues and the regional leagues of eight departments divided over the Netherlands. The highest national league and the highest regional leagues of the eight departments consist of only one group of teams (n=6 or 8). The other leagues contain more groups with 6 teams. In one calendar year, two competition periods are included, the autumn and the spring period, with 10 team matches each. Teams participating in the competitions are allocated to a certain competition level at the start of a season based on their achievements. Each team match contains nine individual matches in which three team members play against three players of the opponent one by one (i.e., three individual matches per player). Furthermore, two members of each team compete at the double-match. Each winning match won counts for one point, so a maximum score of 10 points can be obtained by a team per match. The team with the most points in a competition period becomes champion of its league’s group and will be promoted to the subsequent higher league for the next competition period. Champions of the highest regional league will promote to the lowest national league in this case.

A competition score is calculated per competition period to indicate the player’s individual competition performance. The competition score consists of composite scores based on the player’s competition level and the percentage of matches he or she won during that season (Netherlands Table Tennis Association, 2013a). The calculation of a period’s competition score is based on the official Netherlands Table Tennis Association’s national and regional competitions and can be converted to international standards. All leagues of the regional and national competitions for both youth and adult players and male and female players are compared in this one system taking strength differences between the existing leagues of the official competition of the Netherlands Table Tennis Association into account. As such, a player’s table tennis performance is ranked within a certain competition period compared to all players competing in different leagues. This allows to compare performances in and between players.

Table tennis performance results were obtained from the Netherlands Table Tennis Association’s archives that corresponded with the performance in the final year of the age categories U13, U15 and U18 at the end of the spring season (June), which means at the age of 12, 14 and 17, respectively. These results included two performance outcomes: (1) the national tournament licence, dichotomised as high and low performance, and (2) the competition score.

The players with an A- or B-license were considered the high-performance players in this study. The players with a C or D-license or players who did not participate in a competition and/or tournaments were regarded as the low-performance players. Although a more
sensitive outcome for table tennis performance would be desirable, the data did not justify such approach. Differentiating between A- and B-licensed players was not recommended as the A-licensed players covered only a small amount of the players from which it was questionable whether their table tennis performance significantly differed from the best players with a B-licence. Moreover, the player groups within the low performers (C-licensed, D-licensed and non-participating players) could not be distinguished from each other as these data were not available from the archives. The Netherlands Table Tennis Association only calculates and files performance results for youth players who have obtained an A- or B-licence.

The players’ competition scores used in this study are based on the competition results during the spring seasons (January-May). Like the tournament licence, the Netherlands Table Tennis Association only files competition scores for youth players who have obtained an A- or B-license. The data of the other players about competition class and success rate were untraceable and could therefore not be used for this study.

Statistical analysis
IBM SPSS Statistics 23 (IBM Corp., Armonk, New York, United States of America) was used for the statistical analyses. The normality of the data was evaluated by comparing (1) means and medians and (2) means and standard deviations with minimal and maximal values. Sample characteristics and descriptive statistics are presented for age and sex specific groups.

To assess the predictive value of perceptuo-motor skills for performance, firstly, univari-able and multivariable logistic regression analyses were used with high versus low performance U13, U15 and U18 as outcome variables. An area under curve of at least 0.70 is considered to be adequate (Terwee et al., 2007). Secondly, for the high performance youth players, univariable and multivariable linear regression analyses were used with the final season’s competition score U13, U15 and U18 as outcome. Models were determined for boys and girls separately. In all analyses, age-standardised scores for the perceptuo-motor skills were used. Moreover, the time (years) between the perceptuo-motor skills assessment and the moment of determining the performance result was included as a covariate in all analyses. For the multivariable models, a backward selection procedure was used and variables were included in the model if p<0.10.
Results

The data of a total of 1191 young table tennis players (age 7-10) were analysed in this study. Sample characteristics and descriptive results of perceptuo-motor skills assessment are presented in Table 2 and Table 3, respectively. All test items’ scores of the total group as well as the separate age groups were evaluated as normally distributed. There was only a small number of missing data per test item (<2.7%). Figure 1 presents the high performance players’ competition scores at a certain age during the follow-up. A difference in the number of players per age exists since not all players had reached a certain age yet.

Table 2. Participants’ characteristics of the national talent day

<table>
<thead>
<tr>
<th>Participants</th>
<th>TOTAL GROUP</th>
<th>BOYS</th>
<th>GIRLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N)</td>
<td>(N)</td>
<td>(N)</td>
</tr>
<tr>
<td>Participants</td>
<td>1998-2012</td>
<td>1191</td>
<td>739</td>
</tr>
<tr>
<td>Test age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>59</td>
<td>34</td>
<td>25</td>
</tr>
<tr>
<td>8</td>
<td>176</td>
<td>105</td>
<td>71</td>
</tr>
<tr>
<td>9</td>
<td>366</td>
<td>225</td>
<td>141</td>
</tr>
<tr>
<td>10</td>
<td>590</td>
<td>375</td>
<td>215</td>
</tr>
</tbody>
</table>

*n=number*

Table 3. Descriptive statistics of the perceptuo-motor skills test items for male and female youth table tennis players

<table>
<thead>
<tr>
<th>ITEM</th>
<th>BOYS</th>
<th>GIRLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age 7</td>
<td>Age 8</td>
</tr>
<tr>
<td></td>
<td>n M ± SD</td>
<td>n M ± SD</td>
</tr>
<tr>
<td>Sprint (s)</td>
<td>34 38.3 ± 6.5</td>
<td>105 35.0 ± 4.2</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>34 30.0 ± 6.8</td>
<td>105 28.8 ± 6.9</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>34 23.9 ± 5.2</td>
<td>105 23.0 ± 6.1</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>31 8.9 ± 1.4</td>
<td>99 9.7 ± 1.4</td>
</tr>
<tr>
<td></td>
<td>n M ± SD</td>
<td>n M ± SD</td>
</tr>
<tr>
<td>Sprint (s)</td>
<td>25 38.5 ± 6.5</td>
<td>71 37.1 ± 4.4</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>25 36.8 ± 13.7</td>
<td>71 34.1 ± 11.3</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>25 34.5 ± 13.3</td>
<td>71 29.0 ± 8.7</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>24 7.4 ± 1.1</td>
<td>62 7.9 ± 1.1</td>
</tr>
</tbody>
</table>

*n=number; M=mean; SD=standard deviation.*
Figure 1. Competition scores of the high performance players per age category (1999-2013).
Tables 4 and 5 show the results of the logistic regression analyses. The univariable analyses in boys reveal that the test item “sprint” is a significant predictor for future high or low performance U13, U15 and U18 (p<0.05). Also “throwing a ball” showed to be a significant predictor in boys for high and low performance U13 and U18 (p<0.05, univariable analyses). The best fitting multivariable models included “sprint” and “throwing a ball” for boys U13 and U18. For the multivariable model U15 only “sprint” is included. The areas under the curve for the best fitting models for boys vary from 0.598 to 0.618. In girls, “throwing a ball” was also a significant predictor for U13 and U15 according to the univariable analyses (p<0.05). For the prediction in girls U18, “throwing a ball” just did not reach the level of significance (p=0.061). In contrast to the boys, “speed while dribbling” is determined as a significant predictor for high and low performance in girls U13, U15 and U18 (p<0.05). “Sprint” only was of significant value for girls U15 based on the univariable analysis (p<0.05). The multivariable model for female players U13 and U18 included the test item “speed while dribbling” as significant predictor whereas “sprint” and “throwing a ball” were included for the best fitting model U15 (p<0.05). The areas under the curve for the girls’ multivariable models tend to be higher at the models for girls of the older age categories (U13: 0.589; U15: 0.619; U18: 0.652). The covariate, the time period between the assessment (age 7 -10) and the determination of the table tennis performance, had no significant contribution in any of the models for both boys and girls.
Table 4. Logistic regression analysis to predict future high and low performance in male youth table tennis players.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>B (SE)</th>
<th>OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>High performance</td>
<td>Low performance</td>
<td></td>
</tr>
<tr>
<td>Boys – U13 Univariable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>552</td>
<td>161</td>
<td>391</td>
<td>0.271 (0.097)</td>
</tr>
<tr>
<td>Agility</td>
<td>550</td>
<td>160</td>
<td>390</td>
<td>0.083 (0.107)</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>554</td>
<td>161</td>
<td>393</td>
<td>0.193 (0.102)</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>525</td>
<td>157</td>
<td>368</td>
<td>0.212 (0.098)</td>
</tr>
<tr>
<td>Multivariable model (n=523)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td></td>
<td>0.212 (0.100)</td>
<td>1.237 (1.017-1.504)</td>
<td>0.033*</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td></td>
<td>0.172 (0.099)</td>
<td>1.187 (0.977-1.443)</td>
<td>0.084</td>
</tr>
<tr>
<td>Area under the curve=0.598</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys – U15 Univariable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>462</td>
<td>111</td>
<td>351</td>
<td>0.303 (0.111)</td>
</tr>
<tr>
<td>Agility</td>
<td>460</td>
<td>110</td>
<td>350</td>
<td>0.068 (0.124)</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>464</td>
<td>111</td>
<td>353</td>
<td>0.213 (0.121)</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>435</td>
<td>106</td>
<td>329</td>
<td>0.197 (0.113)</td>
</tr>
<tr>
<td>Multivariable model (n=462)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td></td>
<td>0.303 (0.111)</td>
<td>1.354 (1.089-1.685)</td>
<td>0.006**</td>
</tr>
<tr>
<td>Area under the curve=0.598</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys – U18 Univariable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>326</td>
<td>58</td>
<td>268</td>
<td>0.368 (0.147)</td>
</tr>
<tr>
<td>Agility</td>
<td>324</td>
<td>57</td>
<td>267</td>
<td>0.194 (0.175)</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>328</td>
<td>58</td>
<td>270</td>
<td>0.204 (0.160)</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>299</td>
<td>52</td>
<td>247</td>
<td>0.346 (0.161)</td>
</tr>
<tr>
<td>Multivariable model (n=298)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td></td>
<td>0.274 (0.155)</td>
<td>1.315 (0.970-1.781)</td>
<td>0.077</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td></td>
<td>0.296 (0.164)</td>
<td>1.344 (0.974-1.855)</td>
<td>0.072</td>
</tr>
<tr>
<td>Area under the curve=0.618</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Univariable and multivariable models include the time period between the assessment and determination of the performance outcome as a covariate.

n=number; OR=odds ratio; CI=confidence interval; * p<0.05; **p<0.01
Table 5. Logistic regression analysis to predict future high and low performance in female youth table tennis players.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>B (SE)</th>
<th>OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>High performance</td>
<td>Low performance</td>
<td></td>
</tr>
<tr>
<td>GIRLS – U13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>333</td>
<td>154</td>
<td>179</td>
<td>0.174 (0.118)</td>
</tr>
<tr>
<td>Agility</td>
<td>331</td>
<td>154</td>
<td>177</td>
<td>0.059 (0.128)</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>333</td>
<td>154</td>
<td>179</td>
<td>0.229 (0.121)</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>318</td>
<td>148</td>
<td>170</td>
<td>0.262 (0.119)</td>
</tr>
<tr>
<td>Multivariable model (n=333)</td>
<td>Speed while dribbling</td>
<td>0.229 (0.121)</td>
<td>1.348 (1.063-1.708)</td>
<td>0.014*</td>
</tr>
<tr>
<td>Area under the curve=0.589</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GIRLS – U15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>275</td>
<td>121</td>
<td>154</td>
<td>0.318 (0.137)</td>
</tr>
<tr>
<td>Agility</td>
<td>274</td>
<td>121</td>
<td>153</td>
<td>-0.095 (0.141)</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>275</td>
<td>121</td>
<td>154</td>
<td>0.344 (0.140)</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>260</td>
<td>116</td>
<td>144</td>
<td>0.344 (0.135)</td>
</tr>
<tr>
<td>Multivariable model (n=260)</td>
<td>Sprint</td>
<td>0.239 (0.141)</td>
<td>1.271 (0.964-1.675)</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td>Throwing a ball</td>
<td>0.298 (0.138)</td>
<td>1.347 (1.028-1.764)</td>
<td>0.031*</td>
</tr>
<tr>
<td>Area under the curve=0.619</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GIRLS – U18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>166</td>
<td>56</td>
<td>110</td>
<td>0.174 (0.166)</td>
</tr>
<tr>
<td>Agility</td>
<td>165</td>
<td>53</td>
<td>107</td>
<td>0.466 (0.253)</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>166</td>
<td>56</td>
<td>110</td>
<td>0.756 (0.250)</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>151</td>
<td>50</td>
<td>101</td>
<td>0.353 (0.189)</td>
</tr>
<tr>
<td>Multivariable model (n=166)</td>
<td>Speed while dribbling</td>
<td>0.756 (0.250)</td>
<td>2.130 (1.306-3.474)</td>
<td>0.002**</td>
</tr>
<tr>
<td>Area under the curve=0.652</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Univariable and multivariable models include the time period between the assessment and determination of the performance outcome as a covariate.

n=number; OR=odds ratio; CI=confidence interval; * p<0.05; **p<0.01
The results of the linear regression analyses are summarised in Tables 6 and 7. "Throwing a ball" is shown to be a significant predictor for the competition scores at older ages (U15 and U18) in the high performance male youth players (p<0.05). No predictors were found for boys’ competition scores U13. In the high performance girls, the test items "sprint", "speed while dribbling" and "throwing a ball" are significant predictors U13 according to the univariable analyses (p<0.05). Nevertheless, only "throwing a ball" was significant in the multivariable model at this age (p<0.009). For the high performance girls U15, only one significant predictor remains, "speed while dribbling" (p=0.001). No significant predictors were found to explain the competition score in high performance girls U18. The explained variance of the multivariable models for competition score in boys and girls ranged between 4 and 13%. The time period between the assessment and performance was found as significant contributor to the multivariable model for boys U15 and U18 and girls U15 (p<0.05).

**Table 6. Linear regression analyses to predict future competition score in high performance male youth table tennis players.**

<table>
<thead>
<tr>
<th>Boys – U13</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>B (SE)</td>
<td>p</td>
</tr>
<tr>
<td><strong>Univariable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>157</td>
<td>4.092 (5.201)</td>
<td>0.433</td>
</tr>
<tr>
<td>Agility</td>
<td>156</td>
<td>-2.020 (6.767)</td>
<td>0.766</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>157</td>
<td>4.045 (6.530)</td>
<td>0.537</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>152</td>
<td>5.032 (5.615)</td>
<td>0.372</td>
</tr>
<tr>
<td><strong>Multivariable model</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None of the items was included in the final model.</td>
<td></td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Boys – U15</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>B (SE)</td>
<td>p</td>
</tr>
<tr>
<td><strong>Univariable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>108</td>
<td>7.040 (7.052)</td>
<td>0.320</td>
</tr>
<tr>
<td>Agility</td>
<td>107</td>
<td>-3.368 (9.015)</td>
<td>0.709</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>108</td>
<td>7.171 (9.312)</td>
<td>0.443</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>103</td>
<td>17.609 (7.186)</td>
<td>0.016*</td>
</tr>
<tr>
<td><strong>Multivariable model</strong> (n=103)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>17.609 (7.186)</td>
<td>0.016*</td>
<td></td>
</tr>
<tr>
<td>Time period</td>
<td>31.523 (9.009)</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td><strong>Adj. R²=0.134</strong></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Boys – U18</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>B (SE)</td>
<td>p</td>
</tr>
<tr>
<td><strong>Univariable</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>53</td>
<td>9.011 (10.640)</td>
<td>0.401</td>
</tr>
<tr>
<td>Agility</td>
<td>52</td>
<td>-5.297 (12.827)</td>
<td>0.681</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>53</td>
<td>-9.958 (12.603)</td>
<td>0.433</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>47</td>
<td>25.193 (11.665)</td>
<td>0.036*</td>
</tr>
<tr>
<td><strong>Multivariable model</strong> (n=47)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>25.319 (11.811)</td>
<td>0.036*</td>
<td></td>
</tr>
<tr>
<td>Time period</td>
<td>28.730 (13.176)</td>
<td>0.034*</td>
<td></td>
</tr>
<tr>
<td><strong>Adj. R²=0.127</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Univariable and multivariable models include the time period between the assessment and determination of the performance outcome as a covariate.

n=number; B=regression coefficient; SE=standard error; * p<0.05; ** p<0.01; adj. R²=adjusted explained variance. 
Table 7. Linear regression analyses to predict future competition score in high performance female youth table tennis players.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>B (SE)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GIRLS – U13</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>147</td>
<td>14.145 (7.075)</td>
<td>0.047*</td>
</tr>
<tr>
<td>Agility</td>
<td>147</td>
<td>8.716 (6.879)</td>
<td>0.207</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>147</td>
<td>15.509 (7.101)</td>
<td>0.031*</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>141</td>
<td>15.638 (6.697)</td>
<td>0.021*</td>
</tr>
<tr>
<td>Multivariable model (n=141)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>17.644 (6.641)</td>
<td>0.009**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adj. $R^2$=0.039</td>
<td></td>
</tr>
<tr>
<td><strong>GIRLS – U15</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>120</td>
<td>10.675 (7.616)</td>
<td>0.164</td>
</tr>
<tr>
<td>Agility</td>
<td>120</td>
<td>11.956 (6.941)</td>
<td>0.088</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>120</td>
<td>20.780 (7.326)</td>
<td>0.005**</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>115</td>
<td>12.150 (7.119)</td>
<td>0.091</td>
</tr>
<tr>
<td>Multivariable model (n=120)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>23.911(7.321)</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td>Time period</td>
<td></td>
<td>24.778 (9.177)</td>
<td>0.008**</td>
</tr>
<tr>
<td>Adj. $R^2$=0.100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GIRLS – U18</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Univariable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>52</td>
<td>5.902 (12.127)</td>
<td>0.629</td>
</tr>
<tr>
<td>Agility</td>
<td>52</td>
<td>2.458 (19.003)</td>
<td>0.898</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>52</td>
<td>26.758 (21.522)</td>
<td>0.250</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>46</td>
<td>15.138 (12.906)</td>
<td>0.247</td>
</tr>
<tr>
<td>Multivariable model (n=46)</td>
<td>None of the items was included in the final model.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Univariable and multivariable models include the time period between the assessment and determination of the performance outcome as a covariate.

$n=number; B=regression
coefficient; SE=standard
error; * p<0.05; ** p<0.01; adj. $R^2$=adjusted explained variance.

Discussion

This study focused on the predictive validity of the test items "sprint", "agility", "speed while dribbling" and "throwing a ball" of the Netherlands Table Tennis Association’s perceptuo-motor skills assessment for future performance in youth table tennis players. The results show, that as hypothesised, the test items when measured at age 7-10 are indeed significant predictors with respect to high and low performance as defined in this study for both boys and girls U13, U15 and U18. The test items "sprint", "throwing a ball" and "speed while dribbling" appeared to be the best predictors in the prediction of high and low performance. Moreover, these test items also contributed to the models to predict competition score in the high performance youth players. Nevertheless, the rather low areas under the
curve (<0.7; Terwee et al., 2007) and explained variance (or predicted variances as the independent variables were measured before the dependent variable) reveal that accuracy of the models need to be improved for practical implications concerning talent development.

The results of this study are in line with those found in tennis by Panjan et al. (2010). Similar to our results, perceptuo-motor skills, including both gross motor functioning and ball control (Faber et al., 2015), were pointed out as significant contributors while the accuracy of the prediction models were low. The results also correspond with the findings of Vandorpe et al. (2012) and di Cagno et al. (2014). Both studies showed that non sport-specific perceptuo-motor tests were significant predictors for performance results in young elite gymnasts. Moreover, the study of Pion et al. (2015) revealed that tests assessing perceptuo-motor skills, which were non-specific to volleyball, discriminated between elite and sub elite adolescent volleyball players (p <0.036). The authors conclude that volleyball as a skill-based sport requires a well-developed level of perceptuo-motor skills (Pion et al., 2015). Consequently, it is suggested that perceptuo-motor skills indeed play an important role in the development of young players’ performance level in sports consisting of complex perceptuo-motor tasks. Further studies should also reveal the exact nature of the characteristics measured by such tests.

The complex, multidimensional and longitudinal nature are suggested to cause the difficulties in long term prediction. Probably, a better estimate of the potential can be made when skills are monitored more frequently over time and including data about training, growth and maturation (Huijgen, Elferink-Gemser, Post, & Visscher, 2009; Malina et al., 2005; Silva et al., 2010). Moreover, one must be alert to the presence of sex differences since our results showed some difference between boys and girls with respect to the predictive value of the perceptuo-motor test items. These differences between boys and girls might be, among others things, a consequence of sex differences in maturation and/or task requirements. Girls, in general, reach puberty at an earlier age than boys (Stang & Story, 2005). This implies that high potential female youth players need to be sought at an earlier age than male high potentials to be able to use the most sensitive period of learning perceptuo-motor skills (Knudsen, 2004; Watanabe et al., 2007). Moreover, although, to our knowledge, results about game analysis in youth table tennis players are lacking, it is hypothesised that the game structure differs between boys and girls and over ages as a consequences of the development of physical and mental abilities. From a practical point this means that trainers should also be aware of possible task differences in table tennis on the elite level for both boys and girls over ages. Only then, it is possible to get a better insight in a player’s development and learning curve regarding essential perceptuo-motor skills for their sports.

Furthermore, the estimation of potential is prone to improve by including other factors (Elferink-Gemser et al., 2011; Gillet et al., 2009; Lane et al., 2002; McCullagh et al., 1993; Philips et al., 2010). Regarding the perceptuo-motor domain, it is advised that at least test items for more specific eye-hand coordination tasks are included, in which anticipation, ball control in handling a smaller ball, speed and accuracy are required. These skills are suggested to be highly important in the player’s development (Faber, Elferink-Gemser, Oos-
terveld, & Nijhuis-Van Der Sanden, 2014; Faber, Oosterveld, & Nijhuis-Van Der Sanden, 2014; Rodrigues, Vickers, & Williams, 2002). Since talent development is a multidimensional process, it is recommended to also include other performance characteristics in the domains of anthropometrics, physiological, technical, tactical and psychological skills, as well as environmental characteristics (e.g. parental involvement) to find the crucial indicators for future performance at different ages (Elferink-Gemser et al., 2004). Only the determination of the key factors for success will increase the accuracy of a model, which entails a multidimensional and longitudinal approach for scientific research and during practice (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2007; Elferink-Gemser et al., 2011). Longitudinal monitoring provides the opportunity to better capture the variability within a player compared to cross-sectional designs, which consequently enhances the strength of the prediction models.

Some limitations of this study need to be acknowledged. First, to optimise the power of this study, results from youth players within the test age ranging from 7 to 10 were analysed all together. Consequently, the analyses included different developmental stages in which the models were calculated, especially when the influence of differences in growth and maturation are also considered (Malina et al., 2005; Silva et al., 2010). Corrections for this were made by using age and sex normalised z-scores and including the time period between the assessment and performance outcome as a fixed covariate. Secondly, it must be acknowledged that the subsamples sizes for the models are different. Most of the players analysed in the subsamples U18 are also analysed in U15 and U13, but this does not necessarily means that the opposite is also true since not all youth players had reached a certain age yet. However, no specific cohort effects on the basis of birth year or test year were recognised and the assessments’ outcomes are considered reproducible (Faber et al., 2015). Thirdly, although the test items’ reproducibility is considered sufficiently as variation between the test and retest results was relatively small (Faber et al., 2015) and the sample size of this study is suggested to be substantial for group analyses, caution should be taken into account of evaluating an individual player based on one single measurement. Finally, the study was conducted using data from Dutch youth players participating at the national talent days. Only a few players included in this database were able to perform at international level during their youth career. Moreover, only one of them reached the highest international level at adult age. For this reason, generalisation is possible for the participants of the national talent day, but caution should be taken in the generalisation of the findings for the prediction of elite world class level.

Conclusion

In conclusion, the test outcomes contribute significantly to the prediction models for high and low performance U13, U15 and U18 in both boys and girls. Moreover, also in the high performance players significant predictors are found for boys U15 and U18 and for girls U13 and U15. Nevertheless, as the accuracies of the models are low, it is advised to include...
other determinants for performance to enhance the predictive value of a model for table tennis performance. Talent development is a multidimensional and longitudinal process (Elferink-Gemser et al., 2011; Phillips et al., 2010), and the perceptuo-motor skills assessment is only suited to be a part of a talent development programme. Still, the main advantage of the perceptuo-motor test items compared to scouts observations or ranking to estimate the potential of youth players is that it can better objectify a young player's perceptuo-motor potential and, for that reason, support selection decisions by coaches. Table tennis performance results at an early age (≤10 years) are influenced by differences in table tennis experiences, development and contexts to a great extent. Especially those young players who are not successful in table tennis yet, but show great perceptuo-motor potential by excellent performance on the perceptuo-motor test items, can be discovered by including such assessment as part of the talent developmental programme. It is important to acknowledge that the assessment of perceptuo-motor skills at an early age does not intend to limit any children's freedom of choice to practice a particular sport. It is only intended to identify those children excelling in the perceptuo-motor skills essential for table tennis. Future research should focus on the evaluation of a more extensive perceptuo-motor skills assessment and other crucial factors including longitudinal assessments to find a more valid predictive model for table tennis performance.

Acknowledgments & Funding

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References


Chapter 5

Does an eye-hand coordination test have added value as part of talent identification in table tennis?:
A validity and reproducibility study

Irene R. Faber
Frits G.J. Oosterveld
Maria W.G. Nijhuis-Van der Sanden

CHAPTER 5

Abstract

This study investigated the added value, i.e. discriminative and concurrent validity and reproducibility, of an eye-hand coordination test relevant to table tennis as part of talent identification. Forty-three table tennis players (7-12 years) from national (n=13), regional (n=11) and local training centres (n=19) participated. During the eye-hand coordination test, children needed to throw a ball against a vertical positioned table tennis table with one hand and to catch the ball correctly with the other hand as frequently as possible in 30 seconds. Four different test versions were assessed varying the distance to the table (1 or 2 meter) and using a tennis or table tennis ball. ‘Within session’ reproducibility was estimated for the two attempts of the initial tests and ten youngsters were retested after 4 weeks to estimate ‘between sessions’ reproducibility. Validity analyses using age as co-variate showed that players from the national and regional centres scored significantly higher than players from the local centre in all test versions (p<0.05). The tests at 1 meter demonstrated better discriminative ability than those at 2 meter. While all tests but one had a positive significant association with competition outcome, which were corrected for age influences, the version with a table tennis ball at 1 meter showed the highest association (r=0.54; p=0.001). Differences between the first and second attempts were comparable for all test versions (between -8 and +7 repetitions) with ICC’s ranging from 0.72 to 0.87. The smallest differences were found for the test with a table tennis ball at 1 meter (between -3 and +3 repetitions). Best test version as part of talent identification appears to be the version with a table tennis ball at 1 meter regarding the psychometric characteristics evaluated. Longitudinal studies are necessary to evaluate the predictive value of this test.

Keywords: reproducibility of results, eye-hand coordination, aptitude, racquet sports
Introduction

Table tennis is widely judged as one of the fastest sports, and can be described as a fairly
difficult task. It is an open, complex motor task that requires performance in a constant-
ly changing environment under great time pressure (Gentile, 2000; Schmidt & Lee, 2011;
Woollacott & Shumway-Cook, 2011). High performance in table tennis requires a broad
repertoire of movements allowing quick and responsive adaptation to the continuously
changing conditions (Sève, Saury, Theureau, & Durand, 2002; Woollacott & Shumway-Cook,
2011). Players need to develop outstanding technical skills, fast switching capability to ad-
just stroke techniques, variable, flexible and fast footwork, pronounced ability to react and
anticipate, proper positioning, and balance control (Ak & Koçak, 2010; Akpınar, Devrilmez,
Kirazci, 2012; Horsch, 1990; Muster, 1986). Moreover, also highly developed tactical skills,
decision-making ability, creativity, concentration, competitiveness, apprehension, self-regu-
lation, and willpower are inseparable to excel in this sport (Chu, Chen, Chen, Huang, & Hung,
2012; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Raab, Masters, & Maxwell,
2005). Although it is not the only aspect, table tennis appears significantly on a player's
coordinative ability or motor skills (Schmidt & lee, 2011; Limoochi, 2006; Rossum & Gagné,
1994; Toriola, Toriola, & Igbokwe, 2004).

Talent identification programs in table tennis ought to find gifted youngsters at an ear-
ly stage to educate them to top players effectively and efficiently (Faber, Nijhuis-Van der
Sanden, & Oosterveld, 2012; Régnier, Salmela, & Russell, 1993; Vaeyens, Lenoir, Williams,
& Philippaerts, 2008). Children who are gifted with outstanding natural abilities in the senso-
rimotor domain are suggested to be in advantage to other children by an easier and faster
learning process for this type of sport (Ackerman, 2013; Gagné, 2004). Such an effective
and efficient learning or performance curve might be a predictor of the child's full poten-
tial (Ackerman, 1998; Ericsson, Krampe, Tesch-Römer, 1993). The learning process in table
tennis will be facilitated further starting at a young age (6-12 years) by using the most
sensitive period to develop motor skills (Limoochi, 2006; Knudson, 2004; Watanabe, Savi-
on-Lemieux, & Penhune, 2007). Consequently, assessing natural motor abilities necessary
for table tennis in youngsters (6-12 years) beside cognitive and social-emotional abilities
as part of talent identification seems reasonable to identify high potentials for this sport.
However, the question arises how to measure this giftedness?

Motor tests with proven predictive value for talent identification in table tennis or other
(racquet) sports are lacking (Ackerman, 1998; Lees, 2003). Vandorpe et al. (2012) was
the first to show that general motor coordination tests correlate strongly with competition
results in elite gymnast; the tests explained more than 40% of the variation in competition
performance two years later. The authors suggested that the tests measure a general trait
underlying a wide variety of skills and that they are sensitive enough to give an indication
of potential performance. Probably the measurement of this underlying trait reflects an
essential natural ability for gymnastics (Vandorpe et al., 2012). This is also in accordance
with the idea that to measure future potential one should not assess specific sport skills
themselves in order to limit the influence of training-experience (Vaeyens et al., 2008; Gagné, 2004; Morrow, Jackson, Disch, & Mood, 2011). Although the study of Vandorpe et al. (2012) was conducted in gymnasts (7-8 years), the concept of the study is believed to suit table tennis, because both sports require an ‘early specialisation’ to develop complex motor skills. While for gymnastics dynamic balance seemed the most important predictor for potential, in table tennis eye hand coordination necessary for ball control, speed and rapidity to react on environmental changes, agility, and reaction and anticipation would probably be more adequate predictors (Ak & Koçak, 2010; Akpinar et al., 2012; Horsch, 1990; Muster, 1986).

The Netherlands Table Tennis Association (NTTA) is developing a talent identification assessment (TIDA) to identify gifted table tennis players in the age range of 6-12 years. This TIDA includes seven test items for assessing eye hand coordination, ball control, coordination, speed / rapidity, anaerobic power and agility (Netherlands Table Tennis Association, 2008). Although these test items already seem to measure all underlying motor abilities, the trainers and coaches were not completely satisfied with the assessment regarding eye hand coordination. Two items specifically intend to measure a combination of eye hand coordination, ball control and anticipatory skills by using an aiming-task under different circumstances. However, these test items assess self-induced discrete movements and do not require repetitive movements with the necessity to anticipate and react quickly under time pressure, which is demonstrated to be essential in table tennis (Ak & Koçak, 2010; Akpinar et al., 2012; Bootsma, Fernandez, Morice, & Montagne, 2010; Rodrigues, Vickers, Williams, 2002).

In cooperation with trainers and coaches of the NTTA, a new test item was developed to measure eye-hand coordination and ball control under time pressure (Netherlands Table Tennis Association, 2011). This test item included a non-specific table tennis task with serial movements requiring continuously adapted responses. The new test item was developed for players from 6-12 years of age and practical feasibility was taken into account (Limoochi, 2006; Morrow et al., 2011). After several tryouts and discussion rounds, four different test versions were proposed. Since it was not clear which test version would fit best for talent identification, all versions were investigated on discriminative and concurrent validity, and reproducibility in this study. It was hypothesized that the test could discriminate players from apparent different training levels. Moreover, positive moderate significant associations (r between 0.4 and 0.7) between test and performance results (concurrent validity) were expected in young table tennis players. Reproducibility was hypothesized to be at an acceptable level due to the inclusion of a training-phase, a time-constraint repetitive-performance task and two attempts (Morrow et al., 2011). Eventually, only the test version with the best feasibility regarding above-mentioned aspects will be selected for implementation in the TIDA of the NTTA as part of talent identification. The selected test version together with the other test items will be put under further investigation about their value for talent identification in future studies. This study contributes to an evidence-based TIDA for table tennis, which supports better talent identification in table tennis.
Methods

Ethics Statement
The study protocol and informed consent procedure were approved by the Ethics Committee of the Medical Spectrum Twente (Medical School Twente, Institute for Applied Science, Enschede, the Netherlands; MTC/12307.fab 2-10-2012) in full compliance with the Declaration of Helsinki. Written informed parental consent and player assent were obtained. Furthermore, both the children and their parents have given written informed consent, as outlined in the PLOS consent form, to publication of the video clips.

Study design
To investigate validity the design was two-fold. First, all four test versions of the eye-hand coordination test were evaluated, using the so-called ‘known group method’ (Portney & Watkins, 2009), on their expected ability to discriminate between young table tennis players from national, regional and local training centres. Secondly, the associations between the results of the four test versions and competition outcome were examined for concurrent validity. Furthermore, this investigation used the initial test including two attempts and a test–retest research design to examine the ‘within session’ and the ‘between sessions’ reproducibility, respectively. The time between the initial test and retest was four weeks.

Participants
Young players were recruited from the national and a regional training centre of the NTTA and two local table tennis centres. Players at the national training centre were selected by expert trainers of the NTTA and were suggested to be the most gifted players at that moment throughout the Netherlands. The players of the regional training were selected by the NTTA trainers of the eastern department and were considered to be the most gifted players of that region. The children recruited from the local centre were judged by their trainers as not competent for a regional and/or the national training centre of the NTTA at that moment and also in future. Inclusion criteria were: an age between 6-12 years and being a member of a table tennis club connected to the NTTA. Players with injuries were excluded. Written informed parental consent and player assent were obtained prior to testing.

Figure 1. Eye-hand coordination test set-up
Measurements

Standardization of the test was realized in a protocol that included a detailed description for materials, set-up, assignment, demonstration, training-phase, testing-phase and registering test-scores (Netherlands Table Tennis Association, 2011). Players were instructed to throw a ball to a vertical positioned table tennis table with one hand and to catch the ball correctly with the other hand as frequently as possible in 30 seconds (Figure 1; Video S1, S2, S3, S4). The players were free to use overhand (Video S3, S4) and/or underhand techniques (Video S1, S2) or a combination of both for throwing and catching. Consequently, players were able to use their best motor performance strategies for optimal results, which is analogous with the table tennis context. The test consisted of four test versions in which the distance to the table tennis table (1 or 2 meter) and the type of ball (table tennis or tennis ball) were varied. All test versions included a training-phase and a testing-phase. Players were familiarized with the test during the training-phase; they practiced throwing and catching of the ball six times only before the first attempt. Procedural inaccuracies were corrected during this phase. In the testing-phase, the highest number correctly caught balls in 30 seconds of two attempts was registered as final outcome. No feedback was given during the testing-phase. The total time for testing was about 5-10 minutes per player.

Procedure

All players were assessed under similar conditions at a regular training at their training centre on a Sunday morning. Before testing all participants did a warming-up as part of their training. After warming-up children started with the specific table tennis training and were invited for the eye-hand coordination test one by one. The order of the four different test versions was randomised for the players of all training centres using playing cards. After the test, the youngsters returned to their training. Testers were four physiotherapy students who were trained to the same extent in using the test-protocols. They were familiarized with the test-protocol and instruction and feedback was given during training by an expert-trainer of the NTTA. Ten players from the same regional training centre were recruited for re-testing after four weeks to estimate reproducibility. The retest was conducted by a different tester, because this best matches daily practice where different trainers conduct the motor tests (Streiner & Norman, 2003). The tester of the retest was blinded for the test outcome of the initial test. Competition results (points) were provided by the NTTA to investigate the relationship between test outcomes and table tennis performance. A higher score in competition points was considered as a better performance.
Statistical analysis

PASW Statistics 21 for Windows (SPSS, Inc., Chicago, Illinois, United States of America) was used for the statistical analyses. Normality of test outcomes was evaluated by the Shapiro-Wilk test. Differences in group characteristics were tested using a one-way ANOVA and Bonferroni post-hoc tests for ratio type data, and a chi-square test for frequencies. Then first, ANCOVA and Sidak post-hoc tests were used to test whether the four test versions discriminated between the players from the national, regional and local training centres. Test outcomes of the four test versions were inserted one by one as dependent variables, the training centres as fixed factor, and age and training hours as suggested covariates. Secondly, the relationships between the test scores of all versions and the competition outcome were evaluated using partial correlation coefficients intending to control for age and training hours. Finally, the ‘within session’ and ‘between sessions’ reproducibility were analysed. Bland-Altman plots were used for each test version to provide a visual representations of measurement errors against true values by plotting a) the difference between the values of the two attempts of the initial test versus the mean of these two attempts and b) the difference between the initial test and the retest values versus the mean of initial test and retest scores (Bland & Altman, 1986). Additionally, intraclass correlation coefficients (ICC) were calculated for the ‘within session’ reproducibility based on the one-way random model. For the ‘between sessions’ reproducibility only Bland-Altman analyses were selected, due to the relatively small and homogenous sample that was used for the retest. Alpha was set on 0.05 for significance for all analysis.
Results

In total 43 young Dutch table tennis players (age 7-12 years) from the national, regional and local training centres participated in this study. This included all players of the national training centre of the NTTA (n =13) and all players of the regional training centre of the eastern department (n =11) at that time. From the players recruited at the local club (n =19), six players did not participate in an official competition of the NTTA. Characteristics of the participants are presented in Table 1. No significant differences were found between the three groups regarding gender, age, height, weight and handedness. Yet, training (p <0.001) and competition results (p <0.001) differed significantly between groups.

Table 1. Characteristics of participants

<table>
<thead>
<tr>
<th></th>
<th>TOTAL</th>
<th>NATIONAL</th>
<th>REGIONAL</th>
<th>LOCAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>43</td>
<td>13</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>Boys</td>
<td>26</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Girls</td>
<td>17</td>
<td>5</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Age (years)</td>
<td>10.4 ± 1.4</td>
<td>10.9 ± 1.5</td>
<td>10.4 ± 1.5</td>
<td>10.1 ± 1.4</td>
</tr>
<tr>
<td>7 year olds</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>8 year olds</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>9 year olds</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>10 year olds</td>
<td>12</td>
<td>3</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>11 year olds</td>
<td>11</td>
<td>5</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>12 year olds</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>149 ± 11</td>
<td>150 ± 12</td>
<td>150 ± 12</td>
<td>148 ± 10</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>38 ± 8</td>
<td>37 ± 7</td>
<td>37 ± 7</td>
<td>38 ± 9</td>
</tr>
<tr>
<td>Right-handed</td>
<td>35</td>
<td>9</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Left-handed</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Training (hours*week-1)</td>
<td>6 (0-20)</td>
<td>11 (7-20)</td>
<td>7 (4-11)</td>
<td>2 (0-3)</td>
</tr>
<tr>
<td>Competition (points)</td>
<td>173 (-52-430)</td>
<td>297 (144-430)</td>
<td>188 (72-317)</td>
<td>36 (-52-130)</td>
</tr>
</tbody>
</table>

Data are frequencies, except for age, length and weight (mean ± SD), and training and competition (mean (range)).

Outcomes of each group on all test versions were normally distributed; p-values of the Shapiro-Wilk tests were >0.05. The results of the validity analyses are presented in Table 2. Participants tended to have higher scores on the test versions at 1 meter distance compared to the versions at 2 meter, and also on the test versions with the tennis ball compared to the versions with the table tennis ball. Most children used only underhand techniques for throwing the ball at the test versions. Only five children used a combination
of overhand and underhand techniques (national n=1, regional n=3, local n=1). All four test versions showed a significant difference between the players of the national and the local training centres (p<0.05) and between the players of the regional and local training centres (p<0.05). However, the differences between the players of the national and the regional training centre were not significant for all test versions. These results are based on an ANCOVA using only age as a covariate. Training hours appeared to be a characteristic of the different training centres and not an independent covariate. Influences of training hours can therefore not be estimated correctly in this analysis. A similar problem appeared at the calculation of the partial correlations; they could not be controlled correctly for training hours because of high collinearity with the competition outcomes. Only controlling for age, the results from all test versions but one were significant and positively associated with the competition results (p<0.05). The partial correlation coefficient of the test version at 2 meter distance with a tennis ball did not reach the level of significance. The tests version at 1 meter distance with a table tennis ball showed the strongest association (r=0.54; p=0.001).

Table 2. Results of eye hand coordination by test version (correctly caught balls/30 seconds; mean ± SD)

<table>
<thead>
<tr>
<th>TEST VERSION</th>
<th>NATIONAL (n=13)</th>
<th>REGIONAL (n=11)</th>
<th>LOCAL (n=19)</th>
<th>F (P)</th>
<th>R (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennis ball - 1 m</td>
<td>29 ± 5</td>
<td>26 ± 5</td>
<td>17 ± 7</td>
<td>15.722* (&lt;0.001)</td>
<td>0.51* (=0.002)</td>
</tr>
<tr>
<td>Tennis ball - 2 m</td>
<td>17 ± 5</td>
<td>18 ± 3</td>
<td>12 ± 5</td>
<td>6.616* (=0.003)</td>
<td>0.17 (=0.316)</td>
</tr>
<tr>
<td>Table tennis ball - 1 m</td>
<td>24 ± 7</td>
<td>23 ± 4</td>
<td>14 ± 5</td>
<td>18.507* (&lt;0.001)</td>
<td>0.54* (=0.001)</td>
</tr>
<tr>
<td>Table tennis ball - 2 m</td>
<td>15 ± 6</td>
<td>16 ± 4</td>
<td>9 ± 5</td>
<td>9.747* (=0.001)</td>
<td>0.33* (=0.049)</td>
</tr>
</tbody>
</table>

r: Partial correlation coefficient of association between test and competition results controlled for age.
* p<0.05: Sidak post hoc tests showed significant differences between (1) national and local centres and (2) regional and local centres for all test versions.
Figure 2. Bland-Altman plots for ‘within session’ reproducibility. A. Tennis ball - 1 meter, B. Tennis ball – 2 meter, C. Table tennis ball – 1 meter, D. Table tennis ball – 2 meter. The bold dotted line represents the mean difference (number of correctly caught balls/30 seconds) between the first attempt and second attempt. The non-bold dotted lines represent the 95% limits of agreement (± 1.96×SD). ICC: intraclass correlation coefficients; **p<0.01.

Figure 2 A, B, C, D and Figure 3 A, B, C, D present the Bland-Altman plots for all test versions for the ‘within session’ and ‘between session’ reproducibility, respectively. The mean difference or systematic error of the ‘within session’ analysis were between 0 and 1 correctly caught balls in 30 seconds for all test items (Figure 2 A, B, C, D). The 95% confidence intervals for the difference between the first and second attempt were comparable for the four test versions; between -8 to +9 correctly caught balls in 30 seconds (Figure 2 A, B, C, D). ICC’s calculated for the ‘within session’ reproducibility were significant (p<0.01) and ranged from 0.72 to 0.87.
In general the systematic error in all tests was also small in the 'between session' results (between -1 and +1 correctly caught balls in 30 seconds; Figure 3 A, C, D). Only the test version with a tennis ball at 2 meter distance presented a larger systematic error between the initial test and retest (mean difference = +3; Figure 3 B). The test version with a table tennis ball at 1 meter distance demonstrated the smallest bandwidth on the difference between the test and retest of -3 and +3 correctly caught balls in 30 seconds for 90% of the players retested (Figure 3 C). There seemed to be one outlier (+13). The other test versions had larger differences between the initial test and retest; tennis ball 1 meter between -8 and 7 (Figure 3 A), tennis ball 2 meter between -1 and 6 (Figure 3 B), table tennis ball 2 meter between -7 and 6 (Figure 3 D).

Figure 3. Bland-Altman plots for 'between session' reproducibility. A. Tennis ball - 1 meter, B. Tennis ball – 2 meter, C. Table tennis ball – 1 meter, D. Table tennis ball – 2 meter. The bold dotted line represents the mean difference (number of correctly caught balls/30 seconds) between the initial test and retest. The non-bold dotted lines represent the 95% limits of agreement (± 1.96•SD).
Discussion

The results of this study confirmed that all test items were able to discriminate local training centre players from players of the regional and national training centres, and we found positive moderate significant associations with competition results for three test versions. These main effects included a correction for the influence of age. Moreover, reproducibility was acceptable. The test version with a table tennis ball at 1 meter distance is suggested to fit best in the provisional TIDA of the NTTA as part of talent identification in table tennis, due to the best combination of psychometric characteristics examined in this study. This selected test version together with the other test items of the TIDA must be evaluated further on their predictive value in a longitudinal study including analyses which investigate the main and interaction effect of age.

It is suggested that the better validity and reproducibility results of the test version with a table tennis ball at 1 meter distance is due to the difficulty of that particular test version. Taking the mean values of the four test versions into account for all groups (Table 2), it appears that shortening the distance to the vertical positioned table tennis table improves the discriminative ability by generally enlarging the difference between groups. Due to the shorter distance the load on reaction is higher, and the youngsters had to be most precise and quick in their reactions. Table tennis players with high potential are assumed to be more prone to especially these specific quick reaction tasks than those with low potential (Ak & Koçak, 2010; Akpinar et al., 2012; Gagné, 2004). The demonstrated larger difference between the players of the local training centres and the players of the national training centre in the test versions using the short distance (1 meter) compared to the large distance (2 meter) is considered logical. The ball type, on the other hand, did not influence the discriminative ability between groups in this sample. All groups had lower scores catching the table tennis ball compared to the tennis ball, which can be explained by the extra need for precision using a smaller, lighter, harder and smoother ball (Gentile, 2000; Schmidt & Lee, 2011; Woollacott & Shumway-Cook, 2011). Still, the differences between the three player groups were not larger using a specific ball.

As shown all test versions had the ability to discriminate between the players of the local and other training centres. However, there was no significant difference between the players from the national and the regional training centres in this study. This could most likely be explained that both centres include children with good to excellent motor performance. This is supported by the large overlap between the competition results of both groups (Table 1). Probably, differentiating between players of regional and national training centres is more difficult regarding motor performance than between players of these centres and players of the local training centre. This could be due to other selection criteria for the trainings centres than motor performance like motivation, concentration and self-regulation, and contextual factors like the influence of parents.

This also brings up the question to what extent the test results were influenced by the difference in training experience of the players of the included training centres. Unfortunately, the influence of training could not be estimated in this cross-sectional study, due to
the dependency and collinearity of intended covariate ‘training hours’ with the test groups and the competition results, respectively. Yet, the influence of training was not regarded as a subject in this study. Longitudinal studies are needed to find answers on this matter. It is believed that motor tests can only partly explain future performance, probably by reflecting a preposition or necessity for a certain skill. Deliberate practice is also considered as an essential component in talent development (Ackerman, 2013). One of the main goals of this study was to investigate the discriminative validity of the test versions, and for that purpose a ‘known-group’ design was chosen (Portney & Watkins, 2009). It was the intention to examine players with a known difference in potential. Thus, players were deliberately recruited from different training centres consequently including unavoidable differences in training hours. By selecting a motor task which assesses the eye hand coordination which is close to table tennis, but not a specific task which is practiced during training, it was intended to measure potential and eliminate the effect of training or competition experience. Task specificity theories and studies support this consideration (Di Russo, Pitzalis, Aprile, & Spinelli, 2005; Schoemaker, Niemeijer, Reynders, & Smits-Engelsman, 2003). Anyway, the main result of this study is that the test item is able to discriminate between high and low performers and all factors affecting this difference, which is an essential quality of a test for talent identification. Future studies must reveal the influence of training on test results used as part of talent identification.

Probably also due to the included sample with sufficient low and high potentials, the test results of the versions at 1 meter distance had a moderate significant relationship with the competition outcome as expected. Players from the national training centre were generally thought to be high performers and high potentials and players from the local training centre were generally considered as low performers with low potential. Yet, a strong relationship between test results and ranking was not hypothesized for this sample. Youngsters that have just started do not have that much experience and probably train at the local centres. Consequently, gifted children with little experience in competition have probably low ranking but could be high potentials for table tennis and have outstanding results at the test. And vice versa, less gifted children with a lot of training and competition experience can have a high ranking but disappointing results at the test.

‘Within session’ and ‘between sessions’ reproducibility outcomes were satisfactory. Systematic errors of all test versions in both the ‘within session’ and ‘between session’ estimations were small for all test versions, meaning no substantial learning-effects exist. The random errors shown in the ‘within session’ analyses were quite large. By using the best of two attempts as an outcome of the test versions, this random errors seem to be somewhat reduced by demonstrating a smaller random error in the ‘between session’ analyses. The selected test version for the NTTA’s TIDA with a table tennis ball at 1 meter distance demonstrated the smallest random measurement error between the initial test and the retest. The outlier at the reproducibility analysis (scoring 13 balls more at the retest than at the initial test (figure 3 C) could, according to the trainer, be explained by motivational problems during the initial test. This was also seen at the other test versions, however to a lesser extent; the player caught between 2 to 5 balls more at the retest. The rather high re-
liability parameters (ICC’s) of the ‘within session’ estimations suggest that the players can be distinguished quite well despite measurement errors. When ICC’s could be calculated in a larger sample for the ‘between sessions’ reliability these are expected to show even higher values as a results of a smaller random error (De Vet et al., 2006).

Then, because the protocol did not prescribe a fixed way how to perform the test both overhand as underhand techniques were used for throwing and catching. Most children (n=38) chose to use only underhand techniques, so is not expected that this influenced the results of this study to a large extend. Remarkable was that especially children with high performances on the test selected one strategy after using different strategies at the training-phase and were also able to adapt their strategy fast when necessary. Although technique standardization probably can improve reproducibility, it is advised to retain the freedom for children to choose their own strategy to excel. This is in accordance with the nature of the test and table tennis (Woollacott & Shumway-Cook, 2011; Horsch, 1990; Muster, 1986).

Finally, it must be acknowledged that this study only included a small sample size and only a part of this group participated in the retest. This sample size is due to the small number of talented athletes (best 1-5%). These players were considered crucial to include in this study to make fair conclusions for talent identification, consequently reducing the number of athletes. Compared to the subgroup of talented children however, the included sample is believed representative and generalisation should only be done in this selected subgroup. Moreover, although the sample is rather small, we were able to find significant differences between the children from the different training centres, significant association between the test version and competition results and acceptable reproducibility outcomes.

This study can be seen as the first step towards implementation of an eye hand coordination test in a TIDA for table tennis. The results contribute to an evidence-based talent identification program and will help talent development in future. The test version with a table tennis ball at 1 meter distance will be implemented in the NTTA’s TIDA as part of talent identification. Further research to obtain normative data and to learn more about the predictive value in longitudinal studies and about reproducibility in a larger sample is essential for correct interpretation of individual test scores of the TIDA (Faber, Nijhuis-Van der Sanden, & Oosterveld, 2012; Vaeyens et al., 2008; Ackerman, 2013; Vandorpe et al., 2012). Individual differences due to gender and maturity should also be taken into account (Ackerman, 2013; Helsen, Winckel, & Williams, 2005; Thomas & French, 1985).

Acknowledgements

The authors would like to thank all participants, their parents, the physiotherapy students and the NTTA for their cooperation. Special thanks go to Marije Elferink-Gemser for sharing her expertise on talent development in sports, Niels Faber for his guidance at the statistical topics, and Amy Lenderink-Hylton for her assistance on English writing.
Supporting Information Legends

Video S1. Test version table tennis ball – 1m
doi:10.1371/journal.pone.0085657.s001

Video S2. Test version table tennis ball – 2m
doi:10.1371/journal.pone.0085657.s002

Video S3. Test version tennis ball – 1m
doi:10.1371/journal.pone.0085657.s003

Video S4. Test version tennis ball – 2m
doi:10.1371/journal.pone.0085657.s004
References


Chapter 6

The Dutch motor skills assessment as tool for talent development in table tennis: A reproducibility and validity study

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Maria W.G. Nijhuis-Van der Sanden
Marije T. Elferink-Gemser
Frits G.J. Oosterveld

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Abstract

A motor skills assessment could be helpful in talent development by estimating essential perceptuo-motor skills of young players, which are considered requisite to develop excellent technical and tactical qualities. The Netherlands Table Tennis Association uses a motor skills assessment in their talent development programme consisting of eight items measuring perceptuo-motor skills specific to table tennis under varying conditions. This study aimed to investigate this assessment regarding its reproducibility, internal consistency, underlying dimensions, and concurrent validity in 113 young table tennis players (6-10 years). The intraclass correlation coefficients of six test items met the criteria of 0.7 with coefficients of variation between 3-8%. Cronbach’s alpha valued 0.853 for internal consistency. The principal components analysis distinguished two conceptually meaningful factors: ‘ball control’ and ‘gross motor function’. Concurrent validity analyses demonstrated moderate associations between the motor skills assessment’s results and national ranking; boys r=-0.53 (p<0.001) and girls r=-0.45 (p=0.015). In conclusion, this evaluation demonstrated six test items with acceptable reproducibility, good internal consistency and good prospects for validity. Two test items need revision to upgrade reproducibility. Since the motor skills assessment seems to be a reproducible, objective part of a talent development programme, more longitudinal studies are required to investigate its predictive validity.

Keywords: reproducibility of results, psychomotor performance, aptitude, racquet sports, gifted children
Introduction

Table tennis at elite level is one of the fastest sports, and can be described as a fairly difficult task. It is an open, complex motor task which entails performance under constantly changing conditions and great time pressure (Gentile, 2000; Schmidt & Lee, 2011). Elite training and high performance in this sport are inseparable connected to highly developed tactical skills, decision-making ability, creativity, concentration, competitiveness, apprehension, self-regulation and willpower (Chu, Chen, Chen, Huang, & Hung, 2012; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Raab, Masters, & Maxwell, 2005). However, table tennis also requires a broad repertoire of movements allowing quick and responsive adaptation to the continuously changing conditions (Sève, Saury, Theureau, & Durand, 2002). Players aiming to excel need to develop outstanding technical skills, fast switching capability to adjust stroke techniques, variable, flexible and fast footwork, pronounced ability to anticipate and react, proper positioning, and balance control (Ak & Koçak, 2010; Akipinar, Devrilmez, & Kirazci, 2012; Horsch, 1990; Muster, 1986).

Thus, although talent development is considered a multi-dimensional process (Elferink-Gemser, Jordet, Coelho E Silva, & Visscher, 2011), table tennis appeals significantly to a player’s perceptuo-motor skills (Limoochi, 2006; Rossum & Gagné, 1994; Schmidt & Lee, 2011; Toriola, Toriola, & Igbokwe, 2004). These skills are considered prerequisite to develop adequate technical qualities (German Table Tennis Association, 2008) and can probably be appointed as the underlying fundament of a player for building up outstanding specific sport skills (Faber, Oosterveld, & Nijhuis-Van der Sanden, 2014; Huigen, Elferink-Gemser, Post, & Visscher, 2009; Vandorpe et al., 2012). Moreover, the better technical motor skills are automated, the more possibilities a player has to execute tactical strategies (Kannenks, Elferink-Gemser, & Visscher, 2011). The difficult technical skills of table tennis are considered to be learned best at a young age, i.e. age from approximately 5 years till the pubertal growth spurt (12-14 years) (Stang & Story, 2005), using the most sensitive period for learning motor skills (Knudson, 2004; Limoochi, 2006; Watanabe, Savion-Lemieux, & Penhune, 2007). Consequently, an assessment of perceptuo-motor skills for young players as part of a talent development programme seems sensible (Girard & Millet, 2009; Limoochi, 2006; Vandorpe et al., 2012).

Since 1998, the Netherlands Table Tennis Association uses a motor skills assessment as part of their talent development programme to assess young table tennis players (6-12 years) (Netherlands Table Tennis Association, 2011). Full-time trainers of the German Table Tennis Association with expertise in talent identification originally set up this motor skills assessment. The Netherlands Table Tennis Association’s trainers and coaches further improved the original assessment on the basis of expert opinions and field experiences. Germany has proven itself to be a world class competitor in the past years; men’s and women’s world team ranking within top five and top ten, respectively (www.ittf.com). The German Table Tennis Association still uses a motor skills assessment, including items for assessing perceptuo-motor skills, flexibility, and endurance capacity, but no data of reproducibility and validity are available.
The current motor skills assessment of the Netherlands Table Tennis Association consists of eight test items (Table 1) (Netherlands Table Tennis Association, 2011), which all together assess the following hypothesised essential perceptuo-motor skills for table tennis: eye-hand coordination, coordination of simultaneous foot and arm movements, combined gross and fine motor skills, agility, balance, bat and ball control, and high velocity in footwork and strikes (Faber et al., 2014; German Table Tennis Association, 2008; Horsch, 1990; Rodrigues, Vickers, & Williams, 2002). The test items assess perceptuo-motor skills, without using authentic table tennis tasks. The idea is that skills, which are not trained, are more appropriate to measure future potential than specific sport skills themselves (Gagné, 2004; Morrow, Jackson, Disch, & Mood, 2011; Vaeyens, Lenoir, Williams, & Philippaerts, 2008).

The motor skills assessment is especially added to tournaments plays during the Netherlands Table Tennis Association's annual national talent day. For this day, the eight departments of the Netherlands Table Tennis Association delegate the youngsters (8 boys and 8 girls, age <11 years) who are considered to have the greatest potential to become an elite player. Selections are made by the trainers of the departments. Boys and girls are split up during both the assessment and the tournament. Professional trainers observe the children playing the tournament. The best youngsters, based on a combination of the total score of the motor skills assessment, the tournament and observations of professional trainers, are invited for further selection procedures of the 'talent-group'. This is a training group for the young national elite players (<13 years) of the Netherlands Table Tennis Association following the talent development programme. The motor skills assessment is also used for regular monitoring of the talent-group members; the results from the assessment together with performance results, training aspects, motivation and the observations of the trainers are used for selection and training perspectives in the talent development programme.
Although the Netherlands Table Tennis Association’s motor skills assessment has been used for several years, the psychometric characteristics, such as reproducibility, concurrent validity and predictive value, were never evaluated. This is crucial for obtaining trustworthy results and for the adequate interpretation of the test outcomes (Morrow et al., 2011; Vae-yens et al., 2008). As a first step, this study was designed following the consensus-based standards for the selection of health status measurement instruments (COSMIN) (Mokkink et al., 2010). This study aimed to investigate the motor skills assessment on:

1. its reproducibility on test-item level (COSMIN checklist: Box B and C);
2. its internal consistency (COSMIN checklist: Box A);
3. its possible underlying dimensions or so-called latent variables (COSMIN checklist: Box E);
4. its concurrent validity (COSMIN checklist: Box F).

Reproducibility was hypothesised to be at an acceptable level due to the standardised protocols including training phases before testing, (time constraint) repetitive performance tasks and/or a number of attempts (Morrow et al., 2011). Internal consistency was expected to be sufficient as all test items measure aspects from the sensorimotor domain. There was no a priori hypothesis about the existence of latent variables. Concurrent validity was investigated by examining the relationship with national ranking. Only a moderate relation was expected, because the motor skills assessment is thought to measure an aspect of the underlying fundament for table tennis, whereas national ranking is based on performances

Table 1. Current test items of the motor skills assessment of the Netherlands Table Tennis Association (Netherlands Table Tennis Association, 2011)

<table>
<thead>
<tr>
<th>TEST ITEM</th>
<th>ASSESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint (s)</td>
<td>The ability for quick accelerations and turns (footwork) in combination with a manual task.</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>The ability to quickly coordinate gross arm and leg movements simultaneously while reasonable strength of the upper and lower extremities is required.</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>The ability to combine jumping strength of the lower extremities with a slightly demanding coordinative manual task.</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>The ability to control a ball (eye-hand coordination and fine motor / ball control) during a dynamic task, sideward zigzagging (footwork).</td>
</tr>
<tr>
<td>Aiming at target (points)</td>
<td>The ability to hit a target precisely with ball using a bat (eye-hand coordination and ball control).</td>
</tr>
<tr>
<td>Ball skills (points)</td>
<td>The ability to hit a target precisely under varied conditions; distance to target and ball size (ball control; parameterise power and velocity).</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>The ability to combine the coordination of an arm movement with high arm velocity (combination gross and fine motor skills).</td>
</tr>
<tr>
<td>Eye-hand coordination (points)</td>
<td>The ability to make accurate and cooperative hand and arm movements (eye-hand coordination) at a high rate.</td>
</tr>
</tbody>
</table>
in competition and tournaments and is established by several multidimensional characteristics (Elferink-Gemser et al., 2011), which are not all included in the assessment.

**Methods**

**Ethics Statement**

This study and informed consent procedures were approved by the ethical committee of the Medical Spectrum Twente (Medical School Twente, Institute for Applied Science, Enschede, the Netherlands; MTC/11069.oos 18-2-2011) in full compliance with the declaration of Helsinki. At least 1 month prior to the measurements, players and their parents were informed in writing by the Netherlands Table Tennis Association that data, sampled during events organised by the Netherlands Table Tennis Association, would be anonymously collected for this study. There was full opportunity for players and their parents to ask for more information concerning this study and/or refuse provision of the anonymous results. All data were recorded in an anonymous dataset by the Netherlands Table Tennis Association; the ethical committee consulted waived the need of a written parental and player’s informed consent.

**Design**

This study used a test–retest research design to examine reproducibility. The initial assessments were used for estimating internal consistency and searching for possible underlying dimensions. Furthermore, the association between the motor skills assessment and ranking was examined for concurrent validity.

**Participants**

Young table tennis players were recruited on the national talent day and in the talent-group in 2009 by the Netherlands Table Tennis Association. The players of the national talent day were selected by the regional technical staff to represent their department. Inclusion criteria were: an age between 6 and 10 years and being a member of a table tennis club associated with the Netherlands Table Tennis Association. Players with injuries were excluded from the study.

**Data collection**

All players were assessed with the motor skills assessment under similar conditions at the national sport centre at Papendal on two consecutive Sundays. The participants of the national talent day were examined as a part of the event. The talent-group members were evaluated as a part of their regular monitoring during training. The testers were physiotherapy students who were trained in using the test protocols. They were familiarised with the protocols of the test items and instruction and feedback was given during training by an expert trainer of the Netherlands Table Tennis Association.

To investigate the reproducibility on test-item level, one half of the players (n>50) of the national talent day were retested on four test items, and the other half of the players (n>50)
on the remaining four test items, both during an extra round of testing on the same day. A different tester for retesting was chosen, because this best matches daily practice where different trainers conduct the motor tests. The tester of the retest was blinded for the test outcome of the initial test. For concurrent validity, the performance results, i.e., the national ranking were provided by the Netherlands Table Tennis Association. The national ranking is based on participation in the official competition and national tournaments of the Netherlands Table Tennis Association; both yield points, which determine national ranking when added up.

Measurements

The Netherlands Table Tennis Association’s motor skills assessment consists of eight test items (Table I). The standardisation of the test items was captured in protocols, which included a detailed description for materials, set-up, assignment, demonstration, training-phase, testing-phase and registering test scores (Netherlands Table Tennis Association, 2011). ‘Sprint’ includes a pyramid-shape circuit (isosceles triangle, basis 6m, height 5 m) in which players need to gather and return five table tennis balls one by one as fast as possible. For ‘agility’, players need to get through a circuit, including climbing over a gymnastics’ cabinet (five times) and under and over a low hurdle (four times), as fast as possible. Both ‘sprint’ and ‘agility’ are measured in seconds (s). At ‘vertical jump’ players needed to jump and touch the sidewall as high as possible, which is measured in centimetres (cm). ‘Speed while dribbling’ uses a zigzag circuit in which the players need to move sideways as fast as possible while dribbling one-handed with a basketball. This test is also measured in seconds (s). At ‘aiming at target’ players need to hit alternately two targets (distance 2 and 4 m) with a table tennis ball using a standard bat. ‘Balls skills’ also requires hitting two targets alternately (distance 2 and 3m), but at this item players need to throw a basketball, tennis ball and table tennis ball. At ‘aiming at target’ and ‘ball skills’ players collect one point each time the target is hit correctly (points). At ‘throwing a ball’, the players throw a table tennis ball as far as possible which is measured in metres (m). In the ‘eye hand coordination’ test players are instructed to throw a ball to a vertical positioned table tennis table (1 m distance) with one hand and to catch the ball correctly with the other hand as frequently as possible in 30 s (Faber et al., 2014). The number of correct catches is scored.

To obtain a total score for the motor skills assessment, raw test scores are first converted into age-independent percentile scores per test items. These percentile scores are based on all available test-item data from the national talent days between 1998 and 2010 (sprint n=206; agility n=1122; vertical jump n=513; speed while dribbling n=1127; aiming at target n=308; ball skills n=541; throwing a ball n=954; eye-hand coordination n=207; age 6-10 years). The above-mentioned numbers of participants for determining the percentile scores differ between the test items, because some revisions of the assessment were made by the trainers of the Netherlands Table Tennis Association between 1998 and 2010. The percentile scores range from 0 to 100 points per test item with intervals of 5 points and reflect the position of a player compared to the total population on that specific test item. For example, a percentile score of 100 is given when a player scores equal to the best 5% of the total population, a percentile score of 95 is given when a player scores equal to the
6-10% best of the total population and so on. The total score of the motor skills assessment is computed by adding up the percentile scores of all eight test items (range 0-800 points).

**Statistical analysis**

IBM SPSS Statistics 21 for Windows (IBM Corp., Armonk, NY, USA) was used for the statistical analyses. The normality of the data was evaluated by comparing (1) means and medians of the test items and (2) standard deviation and ranges. Means and standard deviations of the raw scores of the eight test items and the total score were provided for the total group, and split up for boys and girls per age (8-, 9-, 10-year-olds). Influences of gender and age were tested for the total score in the age span of 8-10 years using a univariate general linear model analyses.

Then firstly, as Vet et al. (2006) proposed, reproducibility was used as an umbrella term for both reliability and agreement. Both the reliability and agreement analyses were conducted on the raw scores of each test item. Intraclass correlation coefficient (ICCs) based on the two-way random model (type consistency) and their 95% confidence intervals were calculated as reliability parameters, because the motor skills assessment is used as a discriminative instrument and ranking the players is of main interest (Vet, Terwee, Knol, & Bouter, 2006). For all ICC calculations the ‘single measurement outcomes’ were used. ICCs of 0.7 or more are considered to be acceptable for reliability on test item level (Nunally & Bernstein, 1994). For the agreement parameters the standard error of measurement (SEm), smallest detectable differences (SDD) and coefficient of variation (CV) were calculated with the following formulas (Hopkins, 2000; Vet et al., 2006):

\[
\text{SEm} = \frac{\text{SD difference test-retest}}{\sqrt{2}}
\]

\[
\text{SDD} = 1.96 \cdot \sqrt{2} \cdot \text{SEm}
\]

\[
\text{CV} = \frac{\text{SEm}}{\text{mean of the raw test-item scores}} \cdot 100\%.
\]

These chosen calculations for agreement are consistent with the selection of the reliability parameters. Secondly, Cronbach’s alpha was calculated using the equally directed percentile scores per test item to determine internal consistency of the motor skills assessment. A Cronbach’s alpha of 0.8 was considered to be sufficient (George & Mallery, 2003). Furthermore, to explore associations between the test items, the inter-item correlations based on the percentile scores were given for all test items. Principal components analysis was used to find meaningful underlying dimensions. Only factors with eigenvalues greater than 1.0 were retained for the final rotated solution (oblique rotation). Factor-loading was computed for all test items, loadings <0.3 were suppressed. Finally, the concurrent validity was evaluated by correlating the total test score with the national ranking using the non-parametric Spearman’s correlation coefficient while controlling for age. Because national ranking is gender specific, this analysis was conducted for male and female players separately. Alpha was set on 0.05 for significance for all analyses.
Results

Participants
In total, 113 young table tennis players were assessed as part the Netherlands Table Tennis Association’s national talent day or regular monitoring of the talent-group. No parents or players refused provision of their anonymous data for this study. Table 2 presents the descriptive statistics of the participants. The descriptive results for the raw scores per test item and the total score, without retest data, are presented in Table 3 for the total group and split up for 8-, 9-, and 10-year-old boys and girls. All data of the total group could be evaluated as normally distributed; means and medians were similar and the range around the mean followed a normal distribution. Players of whom part of the data was missing were excluded from the analyses involving that information. The raw scores of the test items demonstrated that boys tended to outperform girls, and the older children score better than the younger ones (Table 3). The main effects of gender and age in the age span from 8 to 10 years for the total score (percentiles added up) were confirmed by the univariate general linear model analyses; gender F=32.323 (p<0.001) and age F=7.404 (p=0.001).

Table 2. Descriptive statistics of young table tennis players

<table>
<thead>
<tr>
<th></th>
<th>TOTAL GROUP</th>
<th>BOYS</th>
<th>GIRLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants (n)</td>
<td>113</td>
<td>66</td>
<td>47</td>
</tr>
<tr>
<td>Age-group (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 years</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>7 years</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8 years</td>
<td>25</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>9 years</td>
<td>42</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>10 years</td>
<td>40</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>TG (n)</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>NT (n)</td>
<td>108</td>
<td>64</td>
<td>44</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>M (RANGE)</td>
<td>M (RANGE)</td>
<td>M (RANGE)</td>
</tr>
<tr>
<td>141 (116-166)</td>
<td>142 (122-166)</td>
<td>140 (116-158)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>33 (21-56)</td>
<td>34 (23-56)</td>
<td>33 (21-53)</td>
</tr>
<tr>
<td>Training (h·week⁻¹)</td>
<td>4 (1-20)</td>
<td>4 (1-20)</td>
<td>4 (1-13)</td>
</tr>
</tbody>
</table>

n=number; M=mean; TG=talent-group; NT=participants of the national talent day
Reproducibility

Table IV summarises the reproducibility outcomes. All test items, except the ones ‘aiming at target’ and ‘ball skills’, meet the criteria of an ICC >0.7 (P<0.05) for reliability (Nunally & Bernstein, 1994). The agreement parameters (SEm, SDD and CV) follow the same trend, which is clearly demonstrated by the CV. The CV of ‘sprint’, ‘agility’, ‘vertical jump’, ‘speed while dribbling’, and ‘throwing a ball’ are between 3% and 8%, whereas the CVs of ‘aiming at target’ and ‘ball skills’ rise up to 26% and 43%, respectively (Table 4).

Table 3. Descriptive statistics of the motor skills assessment (M ± s)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TOTAL</th>
<th>BOYS</th>
<th>GIRLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6-10 years</td>
<td>8 years</td>
<td>9 years</td>
</tr>
<tr>
<td></td>
<td>(n=113)</td>
<td>(n=14)</td>
<td>(n=26)</td>
</tr>
<tr>
<td>Sprint (s)</td>
<td>35 ± 3.8*</td>
<td>35 ± 3.7*</td>
<td>24 ± 2.3</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>30 ± 7.1**</td>
<td>29 ± 6.7</td>
<td>27 ± 6.1*</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>25 ± 5.5*</td>
<td>25 ± 2.5</td>
<td>26 ± 3.7</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>26 ± 7.3</td>
<td>24 ± 5.9</td>
<td>23 ± 4.7</td>
</tr>
<tr>
<td>Aiming at target (points)</td>
<td>7 ± 2.4*</td>
<td>6 ± 2.5</td>
<td>7 ± 2.6</td>
</tr>
<tr>
<td>Ball skills (points)</td>
<td>4 ± 2.0*</td>
<td>4 ± 2.0</td>
<td>4 ± 2.3</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>10 ± 1.6</td>
<td>10 ± 1.3</td>
<td>11 ± 1.4</td>
</tr>
<tr>
<td>Eye-hand coordination (points)</td>
<td>15 ± 7.8</td>
<td>13 ± 7.3</td>
<td>17 ± 5.2</td>
</tr>
<tr>
<td>TOTAL SCORE (percentiles added up)</td>
<td>450 ± 150*</td>
<td>450 ± 130*</td>
<td>520 ± 120*</td>
</tr>
</tbody>
</table>

n=number; M=mean; s=standard deviation; missing values *n=1,**n=2,*n=6.

Table 4. Reproducibility outcomes of the motor skills assessment per item

<table>
<thead>
<tr>
<th>ITEM</th>
<th>n</th>
<th>ICC</th>
<th>ICC 95% CONFIDENCE INTERVAL</th>
<th>SEM</th>
<th>SDD</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint (s)</td>
<td>54</td>
<td>0.79**</td>
<td>0.67-0.88</td>
<td>1.3</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>51</td>
<td>0.80**</td>
<td>0.68-0.88</td>
<td>1.9</td>
<td>5.2</td>
<td>6</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>53</td>
<td>0.73**</td>
<td>0.57-0.83</td>
<td>2.0</td>
<td>5.5</td>
<td>8</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>53</td>
<td>0.83**</td>
<td>0.73-0.90</td>
<td>1.6</td>
<td>4.4</td>
<td>6</td>
</tr>
<tr>
<td>Aiming at target (points)</td>
<td>54</td>
<td>0.53**</td>
<td>0.30-0.69</td>
<td>1.7</td>
<td>4.6</td>
<td>26</td>
</tr>
<tr>
<td>Ball skills (points)</td>
<td>54</td>
<td>0.31*</td>
<td>0.05-0.53</td>
<td>1.8</td>
<td>4.9</td>
<td>43</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>54</td>
<td>0.88**</td>
<td>0.80-0.93</td>
<td>0.3</td>
<td>0.8</td>
<td>3</td>
</tr>
<tr>
<td>Eye-hand coordination (points)</td>
<td>54</td>
<td>0.91**</td>
<td>0.85-0.95</td>
<td>1.0</td>
<td>2.7</td>
<td>7</td>
</tr>
</tbody>
</table>

n: number; ICC: intraclass correlation coefficient (model: two-way random; type: consistency); SEm: standard error of measurement; SDD: smallest detectable difference; CV: coefficient of variation; *p<0.05,**p<0.001.
Internal consistency and principal component analysis

Cronbach’s alpha (Table 5) was estimated at 0.853, which meets the criteria of 0.8 for good internal consistency (George & Mallery, 2003). Deleting any test item reduces the internal consistency to some extent, except for ‘ball skills’ which increases it. Deleting the test items ‘throwing a ball’, ‘eye-hand coordination’ and ‘speed while dribbling’ reduces Cronbach’s alpha the most.

Table 5. Internal consistency of the motor skills assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score</td>
<td>0.853</td>
</tr>
<tr>
<td>If following item is deleted</td>
<td></td>
</tr>
<tr>
<td>Sprint</td>
<td>0.833</td>
</tr>
<tr>
<td>Agility</td>
<td>0.840</td>
</tr>
<tr>
<td>Vertical jump</td>
<td>0.848</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>0.825</td>
</tr>
<tr>
<td>Aiming at target</td>
<td>0.843</td>
</tr>
<tr>
<td>Ball skills</td>
<td>0.858</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>0.813</td>
</tr>
<tr>
<td>Eye-hand coordination</td>
<td>0.818</td>
</tr>
</tbody>
</table>
Chapter 6

Table 6. Inter-item correlation matrix of the motor skills assessment

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Sprint</th>
<th>Agility</th>
<th>Vertical jump</th>
<th>Speed while dribbling</th>
<th>Aiming at target</th>
<th>Ball skills</th>
<th>Throwing a ball</th>
<th>Eye-hand coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint</td>
<td>1.00</td>
<td>0.58</td>
<td>0.49</td>
<td>0.35</td>
<td>0.45</td>
<td>0.23</td>
<td>0.47</td>
<td>0.47</td>
</tr>
<tr>
<td>Agility</td>
<td>1.00</td>
<td>0.58</td>
<td>0.39</td>
<td>0.22</td>
<td>0.15*</td>
<td>0.48</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>Vertical jump</td>
<td>1.00</td>
<td>0.36</td>
<td>0.18</td>
<td>0.15*</td>
<td>0.36</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td></td>
<td>1.00</td>
<td>0.47</td>
<td>0.37</td>
<td>0.72</td>
<td>0.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aiming at target</td>
<td>1.00</td>
<td></td>
<td>0.25</td>
<td>0.48</td>
<td>0.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball skills</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
<td>0.51</td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throwing a ball</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye-hand coordination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

*non-significant, p>0.05.

Table 6 presents the inter-item correlation matrix between all test items using percentile scores. All associations were significant (p<0.05), except between ‘ball skills’ and ‘agility’ (0.15; p=0.058) and between ‘ball skills’ and ‘vertical jump’ (0.15; p=0.062). The lowest significant associations were found between ‘aiming at target’ and the two test items ‘vertical jump’ (0.18; p<0.05) and ‘agility’ (0.22; p<0.05). The highest significant associations were seen between ‘throwing a ball’ and ‘speed while dribbling’ (0.72; p<0.05), ‘eye-hand coordination’ and ‘throwing a ball’ (0.67; p<0.05) and ‘eye-hand coordination’ and ‘speed while dribbling’ (0.66; p<0.05).

The principal components analysis revealed two underlying factors. Table 7 contains the factor-loading matrix of all test items. ‘Speed while dribbling’, ‘aiming at target’, ‘ball skills’, ‘throwing a ball’ and ‘eye-hand coordination’ had high loadings (>0.65) on the first factor, which is suggested as ‘ball control’. The test items with high loadings (>0.65) on the second factor, proposed as ‘gross motor function’, were ‘sprint’, ‘agility’ and ‘vertical jump’. Both factors together explained 65% of the variance. This is in coherence with the results of the inter-item correlation matrix.
Table 7. Factor-loading matrix (oblique rotation)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>FACTOR&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sprint</td>
<td>0.683</td>
</tr>
<tr>
<td>Agility</td>
<td>0.863</td>
</tr>
<tr>
<td>Vertical jump</td>
<td>0.864</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>0.765</td>
</tr>
<tr>
<td>Aiming at target</td>
<td>0.721</td>
</tr>
<tr>
<td>Ball skills</td>
<td>0.721</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>0.785</td>
</tr>
<tr>
<td>Eye-hand coordination</td>
<td>0.739</td>
</tr>
</tbody>
</table>

<sup>a</sup> Labelling factors: 1. Ball control, and 2. Gross motor function

Concurrent validity

The analyses for concurrent validity showed moderate significant negative Spearman’s correlation coefficients for boys and girls while controlling for age; -0.54 (p<0.001) and -0.42 (p=0.025), respectively (Figure 1). This means that children with a high position at the national ranking list tend to reach a higher total score on the motor skills assessment.

![Figure 1](image_url)

**Figure 1.** Relationship between national ranking and total score of the motor skills assessment while controlling for age; A. Boys, B. Girls. TG: members of the talent-group; NT: participants national talent day.
Discussion

This study presents promising results for the psychometric characteristics of the Dutch motor skills assessment for table tennis and meets the COSMIN (Mokking et al., 2010). Firstly, reproducibility appears sufficient for six of the eight test items. Secondly, good internal consistency is confirmed; all test items, except for ball skills, will reduce internal consistency when deleted. Moreover, a moderate relationship was observed between some test items and a principal component analysis distinguished two conceptually recognisable factors: ‘ball control’ and ‘gross motor function’. This confirms the original idea that the motor skills assessment measures several perceptuo-motor skills under varying circumstances. Finally, as hypothesised, this study showed a moderate correlation between the motor skills assessment’s results and actual national ranking for both boys and girls, while controlling for age, confirming concurrent validity.

For reproducible results, it is necessary that a player shows stable performances during testing and retesting. The time indicated test items, i.e., ‘sprint’, ‘agility’ and ‘speed while dribbling’ (Table 1), seem to give steady results with a sufficient range in test scores. This is also the case for ‘vertical jump’, ‘throwing a ball’ and ‘eye-hand coordination’. Reproducibility outcomes of these six test items are similar to such outcomes from other sport tests used in talent development programmes (Ali et al., 2007; Girard & Millet, 2009; Kiphard & Schilling, 2007; Lemmink, Elferink-Gemser, & Visscher, 2004; Vandorpe et al., 2012). The results of the test items ‘aiming at target’ and ‘ball skills’ were unstable; high and low scores seem to be randomly distributed among players. These test items need revision to improve reproducibility and retain the assessment’s structure by preserving the nature of the test items measuring certain specific perceptuo-motor skills. More attempts, fewer variations in subtasks and an extensive scale including more gradations in points for the accuracy of hitting the target could be solutions to get more steady results in these test items while maintaining sufficient responsiveness.

The inter-item correlations and principal component analysis revealed a two-dimensionality in the motor skills assessment. For the test items of the factor ‘ball control’, the main task load seems to be coordinating and controlling a ball, probably by deploying the visuo-motor system for visual acuity and eye-hand coordination in different circumstances. The test items loading on the factor ‘gross motor function’ on the other hand demonstrated a task load on the combination of strength, speed and agility. Regarding these two dimensions, the motor skills assessment seems to cover the most important necessary perceptuo-motor skills in elite table tennis. It appears that the content or face validity by the experts of the German Table Tennis Association and Netherlands Table Tennis Association is reinforced by the exploratory principal component analysis of this study to evaluate its structural validity.

As described earlier, the moderate relations between the motor skills assessment and national ranking were in line with our hypothesis. Both the assessment and the national ranking
are considered to reflect a part of a player's talent or potential capacity to develop into an elite player. Consequently, low correlation coefficients for the relation between the motor skills assessment's results and ranking are unlikely. On the other hand, a strong relation was not expected either, because performance in table tennis is the result of a combination of multidimensional performance characteristics which are influenced by maturation, learning and training (Elferink-Gemser et al., 2011). As a consequence, gifted children with little experience in competition and training probably have a low ranking, but could have outstanding results at the motor skills assessment. And vice versa, less gifted children with a lot of training and competition experience can have a high ranking, but disappointing results at the assessment. Although, these results support the concurrent validity of the motor skills assessment, longitudinal studies must reveal whether it can indeed measure the potential of young players aiming to become elite table tennis players.

Because the motor skills assessment is studied in the context where it is normally used, some concessions were made for feasibility. Firstly, the interval between test and retest was only a couple of hours. For that reason, learning effects and fatigue could have influenced the results. Secondly, one half of the players were retested on four test items, and the other half of the players on the remaining four test items, so no reproducibility analysis is conducted for the total score, which is considered an important outcome. Still, the ecological validity of this study is maximal and including a large sample of the target population was possible, which strengthens extrapolation. Finally, our sample included children from an age-span of 6 to 10 years; however there were only a few children in the age group of 6 to 7 years. Consequently, generalisation of our results is best for players between 8 to 10 years. Additionally, it must be acknowledged that all analyses were based on the results of all participants to optimise the power of the study. Gender and age influences, which were present at the raw scores of the test items and at the total score, might interfere with the analyses of this study. Age influences were expected due to differences in maturation and training in the included age span (Schmidt & Lee, 2011). Gender differences, on the other hand, were not expected, as testing took place in the pre-pubertal phase (Stang & Story, 2005). Although, no large differences are expected for reproducibility and validity analyses due to the distribution of test scores of the subgroups (Table III) and the above mentioned content or face validity by the expert trainers, analyses of subgroups could highlight different accents. Moreover, when norm scores are developed in future, age and gender influences should be taken into account.

In conclusion, in this first comprehensive study about the psychometric characteristics of an instrument for a talent development programme in table tennis that meets the contemporary scientific standards, the investigated motor skills assessment appears to have the capability to measure essential perceptuo-motor skills in young table tennis players with acceptable reproducibility. Consequently, it could be a strong instrument for successful talent development programmes to find and monitor those young players aiming to become elite players. However, to fulfil this perspective it is crucial that the irreproducible test items are revised, the total score of the motor skills assessment is a weighted score of the test
items based on age-dependent percentiles scores, and that validity studies analysing the motor skills assessment are conducted with regard to its ability to discriminate between elite and sub-elite players and with regard to its predictive value in longitudinal designs (Gagné, 2004; Vaeyens et al., 2008). Moreover, for an adequate interpretation of individual test results, it is required that the influence of age, training and maturity are examined (Coelho E Silva et al., 2010; Elferink-Gemser et al., 2011; Helsen, Winckel, & Williams, 2005; Malina et al., 2005). Finally, it must be emphasised that the motor skills assessment is just a part of a broader talent identification programme. Identifying gifted players in table tennis is challenging because of the multidimensionality and the difficulty of predicting outcomes in the future (Brouwers, De Bosscher, & Sotiriadou, 2012; Elferink-Gemser et al., 2011; Vaeyens et al., 2008). Psychological, social and environmental factors also play crucial roles in talent development in table tennis (Elferink-Gemser et al., 2011; Gagné, 2004). Although this study was conducted in young table tennis players, the motor skills assessment’s concept and its fundament can probably be extrapolated to many other sports.

Acknowledgements

We acknowledge the Netherlands Table Tennis Association for the provision of the data, the trainers of the Netherlands Table Tennis Association and physiotherapy students of Saxion University of Applied Sciences for their help with the assessments and of course all children for their participation in this study. Special thanks go to Achim Sialino, technical director of the Netherlands Table Tennis Association, who supported this research from the start, Niels Faber for his guidance at the statistical topics and Nicolien Oldeman for her assistance on English writing. This work was financially supported by Saxion University of Applied Sciences.

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Chapter 7

Revision of two test items of the Dutch Motor Skills Assessment measuring ball control in young table tennis players: A reproducibility and validity study

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Frits G.J. Oosterveld
Maria W.G. Nijhuis-Van der Sanden

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Abstract

In a previous study the Dutch Motor Skills Assessment (MSA), including eight perceptuo-motor tasks, was investigated as a tool for talent development in table tennis. It appeared that two test items, ‘aiming at target’ and ‘ball skills’, needed revision due to irreproducible outcomes. In cooperation with expert trainers of the Netherlands Table Tennis Association new protocols were developed. This study evaluated the reproducibility of the revised test items by means of a test-retest design, and validity by testing the discriminative capacity using a known-group design and the correlation between test outcomes and competition results. Forty-three young table tennis players (6-13 years) from national (n=16), regional (n=12) and local training centres (n=15) participated in this study. Twenty-seven players from the regional and local training centre were retested on the same day. ICC’s for ‘aiming at target’ and ‘ball skills’ were 0.84 (p<0.001) and 0.89 (p<0.001), respectively, with coefficients of variation <20% for both items. Mean outcomes of both revised test items demonstrated the same tendency; mean scores of players from the national centre were the highest, mean scores of regional centre players second highest, and mean scores of local centre players lowest. An ANCOVA using age as covariate and including Sidak post hoc tests, showed that players from the national and local training centre scored significantly differently on both test items (p<0.05) and regional and local players scored significantly differently on ‘ball skills’ (p<0.05). Moreover, a moderate but significant association between the results of ‘aiming at target’ and competition outcome (R=0.53; p=0.003) was found. The results of ‘ball skills’ were not significantly related to competition (R=0.22; p=0.249). Results suggest that the revision resulted in two sufficiently reproducible and valid test items. Longitudinal studies should be conducted to evaluate the predictive value of the test items when incorporated in the MSA.

Keywords: reproducibility of results, psychomotor performance, aptitude, racquet sports, gifted children
Introduction

Table tennis is one of world’s fastest sports in terms of game speed and challenges for a player’s capability of controlling the ball under great time pressure and constantly changing conditions. These conditions are related to the large variety of the flight and rotation of the upcoming ball, the player’s intended return, playing styles and bat materials. High performance in table tennis strongly depends on visual perception and acuity, anticipation, and eye-hand coordination (Ak & Koçak, 2010; Akpinar, Devrilmez, & Kirazci, 2012; Bootsma, Fernandez, Morice, & Montagne, 2010; Faber, Oosterveld, & Nijhuis-Van der Sanden, 2014; Rodrigues, Vickers, & Williams, 2002). All skills need to be extremely well developed and perfectly integrated in stroke techniques, fast and flexible footwork, proper positioning, and balance control (German Table Tennis Association, 2008; Horsch, 1990). Naturally, other qualities such as game-understanding, tactical skills, ability to make decisions, creativity, concentration, competitiveness, volition, and self-management must also be highly developed to outclass in table tennis (Chu, Chen, Chen, Huang, & Hung, 2012; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Raab, Masters, & Maxwell, 2005). Nevertheless, if a player is not able to control the ball in an outstanding way, he may disqualify himself to develop into an elite player. Consequently, formulating criteria for ball control in a Motor Skills Assessment (MSA) as a part of a talent development programme to assess a player’s potential seems logical and maybe even fundamental (Faber, Nijhuis-Van der Sanden, & Oosterveld, 2013; Faber et al., 2014; Van Rossum & Gagné, 1994).

In a previous study, the MSA of the Netherlands Table Tennis Association (NTTA) was evaluated as a tool for talent development in table tennis (Faber et al., 2013). This MSA includes eight test items (Table 1) intending to measure underlying perceptuo-motor skills considered requisite to the ability to develop adequate technical qualities in table tennis. Future potential is believed to be estimated more adequately by assessing such hypothesized essential perceptuo-motor skills under varying circumstances, which performance is not influenced by the quantity of training, rather than by assessing specific sport skills (Faber et al., 2013; Faber et al., 2014; Gagné, 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Vandorpe, Vandendriessche, Vaeyens, Pion, Matthyss, LeFevre, Philippaerts, & Lenoir, 2012). Perceptuo-motor skills are assessed in young table tennis players (6-13 year) as part of a talent development programme, because the necessary technical skills are suggested to be learned best from approximately five years till the pubertal growth (12-14 years) (Stang & Story, 2005) by using the sensitive period for learning motor skills (Knudson, 2004; Limoochi, 2006; Watanabe, Savion-Lemieux, & Penhune, 2007). It is expected that critical time will be lost influencing the potential end level when training to become an elite player starts at a later point in time.

The principal component analyses of the MSA’s first evolution demonstrated that five of the eight test items loaded on the latent variable ‘ball control’ and three test items on ‘gross motor function’. Moreover, it showed fair to good reproducibility, apart from the test items
‘aiming at target’ and ‘ball skills’, both connected to ‘ball control’. The test item ‘aiming at target’ tested whether young players were able to alternately hit two square targets on the floor (2 and 4 m distance) using their own bat. Each player had six attempts and each hit counted for 4 points. The total score was registered the final outcome (Netherlands Table Tennis Association, 2011). With regard to the test item ‘ball skills’, players were instructed to alternately throw a ball with one bounce into two baskets on the floor (2 and 3 m distance). Each player had a total of twelve attempts, using a basketball in the first four attempts, a tennis ball in the following four attempts and a table tennis ball in the final four attempts. Each hit counted for 5 points, the total score of all attempts was registered as final outcome (Netherlands Table Tennis Association, 2011). The results of both ‘aiming at target’ and ‘ball skills’ were unstable and seemed to be based on coincidence too strongly (‘aiming at target’ ICC 0.525 (p<0.01), CV 26%; ‘ball skills’ ICC 0.311 (p<0.05), CV 43%). Additionally, analyses regarding internal consistency showed that deleting the item ‘ball skills’ would even increase the internal consistency of the MSA. Yet, removing the two test items would violate the construct validity of the MSA by the absence of essential perceptuo-motor skills assessing specific aspects of ball control (Faber et al., 2013). The other three items do not specifically cover aiming tasks, including an elongated arm (bat) and scaling ball direction. They focus on ball control in a dynamic situation (‘speed while dribbling’), in combination with arm speed (‘throwing a ball’), and in a repetitive movement task (‘eye-hand coordination’). Consequently, there is an indication for the revision of the test items ‘aiming at target’ and ‘ball skills’ in order to gain more trustworthy results in future.

### Table 1. Current test items of the Dutch MSA (Motor Skills Assessment).

<table>
<thead>
<tr>
<th>TEST ITEM</th>
<th>SHORT DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprint</td>
<td>Pick-up and bring back 6 table tennis balls as fast as possible (pyramid shape sprint)</td>
</tr>
<tr>
<td>Agility</td>
<td>Getting through a circuit as fast as possible; over a gymnastics cabinet and under a low hurdle.</td>
</tr>
<tr>
<td>Vertical jump</td>
<td>Jumping as high as possible.</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>Sideward dribbling through a zigzag circuit.</td>
</tr>
<tr>
<td>Aiming at target</td>
<td>Aiming at a target with bat and ball.</td>
</tr>
<tr>
<td>Ball skills</td>
<td>Aiming at a target with different balls (football, tennis ball, table tennis ball) using one bounce.</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>Throwing a table tennis ball as far as possible.</td>
</tr>
<tr>
<td>Eye hand coordination</td>
<td>Throwing and catching a table tennis ball against a vertical table as often as possible in 30 seconds using alternatively the left and right hand.</td>
</tr>
</tbody>
</table>

New test protocols for the two test items were developed in cooperation with the expert trainers of the NTTA while taking the following recommendations for revision made by Faber et al. (2013) into account: more attempts, fewer variations in subtasks and a more extensive scale for the target. These recommendations were thought to provide more con-
stant results, while maintaining sufficient responsiveness. Additionally, the expert trainers’ main task was to preserve the nature of the test-item in assessing the intended specific perceptuo-motor skills to maintain the proposed construct of the MSA. The revised test items were developed for young table tennis players (6-12 years) and practical feasibility aspects were taken into account. After several trials and discussions, new test protocols were proposed for both test items and put under investigation to evaluate their reproducibility, discriminative validity, and concurrent validity in this study. In line with a previous study (Faber et al., 2013), the reproducibility was hypothesized to be at an acceptable level due to the inclusion of a training-phase, less variation in subtasks, a target with a centre and outer circle, and several attempts (Faber et al., 2014; Morrow, Jackson, Disch, & Mood, 2011). Moreover, it was expected that the test items could discriminate players from apparent different training levels and a positive moderate significant associations (R between 0.4 and 0.7) between test and performance results (concurrent validity) existed in young table tennis players. Assuming that the revised test items demonstrate acceptable reproducibility and validity, they will eventually be included in the NTTA’s MSA and will be evaluated in further detail with regard to their value for talent development.

Materials and methods

Study design

This study used a test–retest design to examine reproducibility. The initial test and retest were conducted on the same day with a minimum time of one hour and a maximum time of two hours between the tests. Additionally, the design to evaluate the validity served two purposes. First, both revised test items were evaluated with regard to their expected ability to discriminate between young table tennis athletes from national, regional and local training level, using the so-called ‘known group method’ (Portney & Watkins, 2009). Secondly, the associations between the results of the revised test items and competition outcome were examined. The study was conducted in full compliance with the Declaration of Helsinki. The study protocol and informed consent procedures were approved by the Ethics Committee of the Medical Spectrum Twente (Medical School Twente, Institute for Applied Science, Enschede, the Netherlands; MTC/12307.fab 2-10-2012).

Players

Young players were recruited from the national and a regional training centre of the NTTA and at a local table tennis centre. Players at the national training centre were selected by expert trainers of the NTTA and were suggested to be the high potential players at that moment throughout the Netherlands. The players of the regional training were selected by the NTTA trainers of the department for the eastern part of the country, and were considered to be the high potential players of that region. The young players from the local training centre were currently considered insufficiently skilled at this point in time, nor are they expected to be selected for a regional and/or national training centre of the NTTA in the future. Inclusion criteria were: an age between 6-13 years and being a member of a table tennis club.
connected to the NTTA. Children with injuries were excluded. Written informed parental consent and player assent were obtained prior to the testing.

Measurements
The standardization of the revised test items was covered in a protocol, which included a detailed description of the materials, set-up, assignment, demonstration, training phase, testing phase and recording test scores (Netherlands Table Tennis Association, 2012).

Aiming at target - revised
The player needed to hit a round target (Ø 0.60 m) on the floor at 2.5 m distance with a table tennis ball using a standard bat (Fig. 1a). Forehand and backhand need to be used alternately during the ten attempts. During the training phase the players practised hitting four times. A hit in the centre (Ø 0.20 m) or the outer ring of the target yielded 6 and 4 points, respectively. The total score of ten attempts was registered as the final outcome. The total time for testing was about 3 minutes per player.

Ball skills - revised
The player needed to hit a round target (Ø 0.75 m) on the floor via a table tennis table in vertical position by throwing a table tennis ball (Fig. 1b). The player had to alternately stand at a 1 m (Fig. 1b: A) and 2 m (Fig. 1b: B) distance from the target. Each player had a total of twenty attempts. During the training phase the players practised six times. A hit in the centre (Ø 0.335 m) or the outer ring of the target yielded 2 and 1 points, respectively. The total score of the twenty attempts was registered as the final outcome. The total time for testing was about 3 minutes per player.
Procedure

All players were assessed under similar conditions during a regular training session at their own training centre on a Sunday morning. Prior to testing, all participants did a warming up as part of their training. After warming up, the children started with the specific table tennis training and were invited to participate in the tests in pairs. After the tests, the players returned to their training. The testers were physiotherapy students who were trained to the same extend in using the test protocols. The players from the regional and local training centres were recruited for retesting by a different tester on the same day to estimate reproducibility. The retest was carried out by a different tester as different trainers conduct the tests in daily practice (Streiner & Norman, 2003). Performance results i.e. competition outcome (points) and an estimation of their training hours per week were provided by the NTTA.

Statistical analysis

IBM Statistics 21 for Windows (IBM Corp., Armonk, New York, United States of America) was used for the statistical analyses. Normality of the test outcomes was evaluated by using the Shapiro-Wilk test. Possible differences in group characteristics between the play-
ers from the different training centres were tested using a one-way ANOVA including Sidak post-hoc tests and a chi-square test for ratio type data and frequencies, respectively.

Reproducibility was used as an umbrella term for both reliability and agreement (De Vet et al., 2006). Both reliability and agreement analyses were conducted on the final outcomes of each test-item. Intraclass correlation coefficients (ICC) based on the two-way random model (type consistency) and the 95% confidence intervals were calculated as reliability parameters, because the MSA is used as a discriminative instrument and the main interest is to rank players (De Vet, Terwee, Knol, & Bouter, 2006). The single measurement outcomes were used for all ICC calculations. ICC’s of 0.7 or more are considered to be acceptable with regard to reliability on test item level (Nunally & Bernstein, 1994). For the agreement parameters the standard error of measurement (SEm), smallest detectable differences (SDD), and coefficient of variation (CV) were calculated on the basis of the following formula’s (De Vet et al., 2006; Hopkins, 2000):

\[
\text{SEm} = \text{SD difference_test-retest} / \sqrt{2},
\]

\[
\text{SDD} = 1.96 \cdot \sqrt{2} \cdot \text{SEm},
\]

\[
\text{CV} = \text{SEm} / \text{mean} \cdot 100\%.
\]

These calculations are consistent with the selection of the reliability parameters. Moreover, Bland-Altman plots were used to provide a visual representations of measurement errors against true values by plotting the mean of initial test and retest scores versus the difference between the initial test and the retest values (Bland & Altman, 1986).

For the first part of the validity analysis, ANCOVA and Sidak post-hoc tests were used per revised test item to test whether the items could discriminate between the players from the three different training centres. The test outcomes were used as dependent variables, the type of training centre as fixed factor, and age as a suggested covariate. The relations between the test scores of the two test items and the competition outcomes were evaluated in the second part of the validity analysis using partial correlation coefficient to correct for the influence of age. Training experience was considered a characteristic of the training centres included, and proved to be inadequate as independent covariate with regard to both validity analyses (Faber et al., 2014). Alpha was set at 0.05 for significance for all analyses.
Results

A total of 43 young table tennis players (age 6-13 years) from national (n=16), regional (n=12) and local training-level (n=15) participated in this study (Table 2). This included all players of the national training centre and the regional training centre of the department for the eastern part of the country at that moment. Seven of the players from the local centres did not compete in official NTTA competitions. The data of three players with regard to left- or right-handedness were missing. The group characteristics of the three training centres did not differ significantly concerning sex, age, height, weight, and left- or right-handedness (p>0.05). The number of hours of training per week and competition points on the other hand, differed significantly between the three groups (p<0.001). The test outcomes of the revised test items of each training centre were distributed normally; p-values of the Shapiro-Wilk tests were >0.05 for the data of both test items.

Table 2. Characteristics of participating young table tennis players.

<table>
<thead>
<tr>
<th></th>
<th>TOTAL</th>
<th>NATIONAL</th>
<th>REGIONAL</th>
<th>LOCAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>22</td>
<td>8</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Girls</td>
<td>21</td>
<td>8</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Age (years)</td>
<td>10.7±1.5</td>
<td>10.9±1.4</td>
<td>10.6±0.8</td>
<td>10.7±2.0</td>
</tr>
<tr>
<td>6 year olds</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>7 year olds</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>8 year olds</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9 year olds</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10 year olds</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>11 year olds</td>
<td>14</td>
<td>3</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>12 year olds</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>13 year olds</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>148±11</td>
<td>147±9</td>
<td>148±10</td>
<td>150±14</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>37±8</td>
<td>33±6</td>
<td>37±9</td>
<td>39±9</td>
</tr>
<tr>
<td>Right-handed</td>
<td>32</td>
<td>13</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Left-handed</td>
<td>8</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Training (hours/week)</td>
<td>6(1-20)</td>
<td>9(5-20)</td>
<td>6(4-8)</td>
<td>2(1-5)</td>
</tr>
<tr>
<td>Competition (points)</td>
<td>214(16-480)</td>
<td>304(163-480)</td>
<td>172(44-279)</td>
<td>82(16-224)</td>
</tr>
</tbody>
</table>

Data are frequencies, except for age, height, and weight (mean ± SD), and training and competition (mean (range)).
Figure 2-5, and Table 3 summarize the reproducibility outcomes. The Bland-Altman plots (Fig. 2; Fig. 4) and the scatter plots (Fig. 3; Fig. 5) of both tests show by a positive mean difference and a positive intercept, that players tended to have higher scores at the retest than the initial test. The revised test items meet the criteria of an ICC>0.7 (p<0.05) for reliability (Nunnally & Bernstein, 1994). Furthermore, the agreement parameters show a SDD of 14.6 points and 6.3 points and CV of 19% and 14%, respectively for the test items ‘aiming at target’ and ‘ball skills.

Table 3. Reproducibility outcomes.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>n</th>
<th>ICC</th>
<th>ICC 95% confidence interval</th>
<th>SEm</th>
<th>SDD</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aiming at target</td>
<td>24</td>
<td>0.838*</td>
<td>0.662-0.927</td>
<td>5.3</td>
<td>14.6</td>
<td>19</td>
</tr>
<tr>
<td>Ball skills</td>
<td>26</td>
<td>0.894*</td>
<td>0.779-0.951</td>
<td>2.3</td>
<td>6.3</td>
<td>14</td>
</tr>
</tbody>
</table>

n: number; ICC: Intraclass Correlation Coefficient (model: two-way random; type: consistency); SEm: Standard Error of measurement; SDD: smallest detectable difference; CV: coefficient of variation; *p<0.001.

The results of the validity analyses are presented in Table 4. For the two revised test items, there was a trend that the mean scores of the players from the national training centre were the highest, the mean scores of the players from the regional centre the second highest, and the players from the local training centre the lowest. The ANCOVA and Sidak post hoc, using age as a covariate, revealed that the players from the national and local centres scored significantly differently on the two revised items (p<0.05), and the players from the regional and local centres had significantly different scores on ‘ball skills’ (p<0.05). Furthermore, the revised item ‘aiming at target’ demonstrated a significant, moderate association between the test outcomes and competition results (R=0.52, p=0.003), while controlling for age. Yet, no significant association was found between the test outcomes of ‘ball skills’ and the competition results (R=0.22, p=0.249).

Table 4. Mean test outcome (±SD) and results of validity analyses.

<table>
<thead>
<tr>
<th>REVISED TEST ITEM</th>
<th>NATIONAL (n=13)</th>
<th>REGIONAL (n=11)</th>
<th>LOCAL (n=19)</th>
<th>F (p)</th>
<th>R (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aiming at target (points)</td>
<td>37±8</td>
<td>30±9</td>
<td>22±15</td>
<td>6.900a (=0.003)</td>
<td>0.52 (=0.003)</td>
</tr>
<tr>
<td>Ball skills (points)</td>
<td>20±6</td>
<td>18±6</td>
<td>12±7</td>
<td>7.444a (=0.002)</td>
<td>0.22 (=0.249)</td>
</tr>
</tbody>
</table>

F: F-value of ANCOVA among the three groups.
R: Partial correlation coefficient of association between test and competition results controlled for age.
a p<0.05: Sidak post hoc tests showed significant differences between the national and local training centres for ‘aiming at target’ and between the national and local centres and between the regional and local centres for ‘ball skills’.
Figure 2. Bland-Altman plot for ‘aiming at target’.
The bold dotted line represents the mean difference between the initial test and retest. The non-bold dotted lines represent the 95% limits of agreement (± 1.96·SD).

Figure 3. Original test versus retest ‘aiming at target’.

\[ y = 0.7843x + 9.6603 \]

\[ R^2 = 0.70616 \]
Figure 4. Bland-Altman plot for ‘ball skills’.
The bold dotted line represents the mean difference between the initial test and retest. The non-bold dotted lines represent the 95% limits of agreement (± 1.96*SD).

Figure 5. Original test versus retest ‘ball skills’.

\[
y = 0.7856x + 6.1274 \\
R^2 = 0.81533
\]
Discussion

The results of this study indicate that the revised test items ‘aiming at target’ and ‘ball skills’ are sufficiently reproducible and valid. The revision of the test items improved the stability of the test outcomes and thus the reliability and agreement parameters. Furthermore, the expected hierarchy was confirmed in the test outcomes of the players of the national, regional, and local training centre, and the revised test items are able to significantly discriminate national training centre players from the local training centre players while controlling for age. A significant difference was found between the players from the regional centre and players of local training centres with regard to ‘ball skills’ and a significant positive association was found between ‘aiming at target’ and competition performance. Consequently, both revised test items are suggested to suit the NTTA’s MSA as part of their talent development programme by measuring specific aspects of ball control. The MSA, including the revised test items, must be evaluated further in a new sample with regard to its structure using a confirmatory factor analysis and with regard to its predictive value in a longitudinal design.

The reproducibility outcomes were satisfactory. Although some learning effect exists, players tended to have better results at the retest than the initial test, revisions in the test protocols ensured acceptable reliability for both items. The reliability parameters are now similar to the values of the other test items within the MSA (Faber et al., 2013) and other instruments (Ali et al., 2007; Girard & Millet, 2009; Kiphard & Schilling, 2007; Lemmink, Elferink-Gemser, & Visscher, 2004; Vandorpe et al., 2012), which means that is possible to differentiate or rank young table tennis players by means of the revised test items to an acceptable extent (De Vet et al., 2006; Hopkins, 2000). Unfortunately no re-testing could be done at the national training centre. As a result of this, reproducibility analyses were not conducted on the basis of the total range in which the players scored. It is expected, however, that the reliability parameters in particular will improve even more by including players from the national centre by extending the range of the test scores (De Vet et al., 2006; Hopkins, 2000). The agreement parameters are also at an acceptable level. The remaining variability of the performance within the players is believed to be coherent with learning a new task. The SDDs show that to distinguish two players from each other based on the results of ‘aiming at target’ and ‘ball skills’, players must differ at least 15 and 7 points, respectively.

The ability of the test items to discriminate the national and local training centre players, and the difficulty to discriminate regional players from other players are in line with the findings of Faber et al. (2014). Also in this study, this may be explained by an overlap in the inclusion of children of the specific training centres with regard to motor performance. The large overlap of the competition points of the national and regional training centre players and of the regional and local players (Table 1) supports this. As proposed by Faber et al. (2014), this could be due to other selection criteria than motor performance (e.g. motivation, concentration, and self-management) for the regional and national training centres and...
environmental factors (e.g. parents). As a result, players with similar motor potential could be selected for different training centres.

The concurrent validity of ‘ball skills’ was not confirmed in this study; only a low non-significant association with competition results was found instead of the hypothesized moderate association. The test item ‘ball skills’ assesses a player’s ability to scale force, speed, and direction in order to realise an optimal ball flight for hitting a target using an untrained and non-sport-specific motor task, which was expected to result into a moderate association of the test outcomes and competition results. The lower association found is probably a consequence of the overlap between the players from the different training centres regarding motor performance combined with the absence of the competition results of seven players of the local training centre. These local players had low test scores, and are considered to be low performers. The lack of these data for the concurrent validity analysis and the overlap between the other players reduced the variety in the data and thus the correlation coefficient.

Although these aspects also apply to ‘aiming at target’, a significant, moderate association was found for this item. This higher significant association is suggested to be due to the greater consistency of this item with specific skills trained table tennis. It was our intention to assess underlying perceptuo-motor skills by using untrained and non-sport specific motor tasks (Faber et al., 2014; Gagné, 2004; Morrow et al., 2011; Vaeyens et al. 2008; Vandorpe et al., 2012). Although the exact task of ‘aiming at target’ in all probability is never trained, it included some aspects specific for table tennis (NTTA 2012): the use of a bat and a table tennis ball, and the distance from the target is similar to the distance on the table. This was due to the fact that the assessment of hitting accuracy at that specific distance using a bat is considered an essential perceptuo-motor skill by the expert trainers of the NTTA. The low and moderate correlation coefficients of the items ‘balls skills’ and ‘aiming at target’, respectively, may indicate that training influences were limited, but it remains unclear to which extent training experience could have influenced the test outcomes. Longitudinal studies are to reveal this as ‘training experience’ is not an independent covariate in this study.

Finally, acknowledging that this study included only a small sample is important. This is due to the fact that only a small number of talented table tennis players (best 1-5%) is available, considered crucial for inclusion in this study to make a fair interpretation. Although only 43 players participated, it is believed to be a representative sample of young table tennis players and generalisation is possible for this subgroup. In addition, despite the small sample, we were able to find significant results for validity and reproducibility.

In conclusion, the results of this study indicate a satisfactory revision of the test items ‘aiming at target’ and ‘ball skills’ and contribute to an evidence-base talent development programme for table tennis and probably other racket sports. The revised protocols can be implemented in the NTTA’s MSA as part of their talent development programme to main-
tain and reinforce the original construct. Further research to obtain reproducibility and normative data in a larger sample, and to learn more about the predictive value in longitudinal studies is essential for a good interpretation of individual test scores (Ackerman, 2013; Vaeyens et al., 2008; Vandorpe et al., 2012). Gender and maturity influences on individual performances should also be taken into account (Ackerman, 2013; Helsen, Winckel, & Williams, 2005; Thomas & French, 1985). In addition, it should be emphasized that the MSA only partly covers the fundament of high potentials. As in many other sports, psychological, social and environmental factors are also believed to play crucial roles in talent development in table tennis (Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011; Gagné, 2004). Moreover, the results of this study should not be used to limit the freedom of choice in children to practice (more than) a particular sport. Trainers and coaches should also be aware of the potential risks of early specialization and selection at such a young age (e.g. injuries, mental exhaustion and drop-outs) (Baker, Côté, & Deakin, 2005; Wall & Côté, 2007). The MSA is only intended as part of a talent development programme to identify those children that excel in perceptuo-motor skills essential for table tennis.

Acknowledgments

The authors would like to thank all participants, their parents, the trainers of the national, regional, and local training centres, the physiotherapy students and the Netherlands Table Tennis Association for their cooperation. Financial support was provided by Saxion University of Applied Sciences and the Dutch Olympic Committee* Dutch Sports Federation in the context of a national talent identification project in sports.

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Chapter 8

Can perceptuo-motor skills assessment outcomes in young table tennis players (7-11 years) predict future competition participation and performance?:
An observational prospective study

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Niels R. Faber
Frits G.J. Oosterveld
Maria W.G. Nijhuis-Van der Sanden

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Abstract

Forecasting future performance in youth table tennis players based on current performance is complex due to, among other things, differences between youth players in growth, development, maturity, context and table tennis experience. Talent development programmes might benefit from an assessment of underlying perceptuo-motor skills for table tennis, which is hypothesized to determine the players’ potential concerning the perceptuo-motor domain. The Dutch perceptuo-motor skills assessment intends to measure the perceptuo-motor potential for table tennis in youth players by assessing the underlying skills crucial for developing technical and tactical qualities. Untrained perceptuo-motor tasks are used as these are suggested to represent a player’s future potential better than specific sport skills themselves as the latter depend on exposure to the sport itself. This study evaluated the value of the perceptuo-motor skills assessment for a talent developmental programme by evaluating its predictive validity for competition participation and performance in 48 young table tennis players (7-11 years). Players were tested on their perceptuo-motor skills once during a regional talent day, and the subsequent competition results were recorded half-yearly over a period of 2.5 years. Logistic regression analysis showed that test scores did not predict future competition participation (p>0.05). Yet, the Generalized Estimating Equations analysis, including the test items ‘aiming at target’, ‘throwing a ball’, and ‘eye-hand coordination’ in the best fitting model, revealed that the outcomes of the perceptuo-motor skills assessment were significant predictors for future competition results ($R^2=51\%$). Since the test age influences the perceptuo-motor skills assessment’s outcome, another multivariable model was proposed including test age as a covariate ($R^2=53\%$). This evaluation demonstrates promising prospects for the perceptuo-motor skills assessment to be included in a talent development programme. Future studies are needed to clarify the predictive value in a larger sample of youth competition players over a longer period in time.

Keywords: psychomotor performance, aptitude, racquet sports, gifted children, reproducibility of results
Introduction

Assessing the potential of young table tennis players to become elite players is extremely difficult since long-term success is less predictable because of (among other factors) the multidimensionality of the performance characteristics in elite sports and the influence of personal development and learning curves (Elferink-Gemser, Jordet, Coelho-E-Silva, & Visscher, 2011; Philips. Davids, Renshaw, & Portus, 2010; Unierzyski, 2006). Nevertheless, criteria based on the maximum potential of a player are expected to be essential for the selection and monitoring of young players of successful talent development programmes to increase the effectiveness of personal coaching and increased training facilities (Faber, Nijhuis-Van der Sanden, & Oosterveld, 2012; Gagné, 2004; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Vandorpe et al., 2012). At this moment, ranking position and scout's observations often form the basis of selection criteria. Ranking position at a young age (<14 years) and junior age (<18 years / <21 years), however, has proven to be a poor indicator of a player's potential, as it is not likely to predict future success in the long term, i.e. adult success (Brouwers, De Bosscher, & Sotiriadou, 2012; Heller, 2008; Reid, Crespo, Santilli, Miley, & Dimmock, 2007). Moreover, since table tennis performance itself is influenced by individual differences in growth, maturation, development and learning curves, training experiences, competition participation and environmental factors, scouts experience difficulties in finding youth players with the highest potential for elite table tennis and in explaining this explicitly (Elferink-Gemser et al., 2011; Philips et al., 2010). Although measuring potential in a developing child is challenging, innovative solutions to find 'diamonds in the rough' might improve the success rate of talent development programmes in table tennis.

Table tennis is regarded as one of the fastest sports in terms of game speed (Abernethy, 1991). Players aiming to excel need to develop excellent perceptuo-motor and anticipatory skills to be able to make quick and responsive adaptations to continuously changing conditions (Abernethy, 1991 Ak & Koçak, 2007; Akpınar, Devrilmes, & Kırazçı, 2012; Horsch, 1990; Kovacs, 2007). Moreover, they must learn to master outstanding tactical skills and withstand the physical demands (Kondrič, Zagatto, & Sekulić, 2013; Lees, 2003; Raab, Masters, & Maxwell, 2005). Inseparable from this, mental aspects, such as concentration and mental toughness, need to be optimised during the extensive development programme to reach an elite level. Not to mention, volition, self-regulation, and social skills are crucial factors for persevering throughout this training process for many years (Chu, Chen, Chen, Huang, & Hung, 2012; Lees, 2003; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Lubbers, 2006).

Yet, although talent development in table tennis is acknowledged as a multi-dimensional process, table tennis at elite level appeals significantly to a player’s perceptuo-motor skills (Limoochi, 2006; Rossum & Gagné, 1994; Schmidt & Lee, 2011; Toriola, Toriola, & Igbokwe, 2004). These skills are considered fundamental in developing outstanding technical skills specific to table tennis (i.e. strokes under varying circumstances) (Faber, Oosterveld, & Nijhuis-Van der Sanden, 2014a; German Table Tennis Association, 2008). The
optimal automation of technical skills also entails better possibilities for a player to execute tactical strategies (i.e. using an adequate solution to handle the specific demands in a situation) (Kannekens, Elferink-Gemser, & Visscher, 2011). The complex technical skills of table tennis are learned best at the age of approximately 5 years till the pubertal growth spurt (12-14 years) (Stang & Story, 2005), using the most sensitive period for learning perceptuo-motor skills (Knudson, 2004; Limoochi, 2006; Watanabe, Savion-Lemieux, & Penhune, 2007). Consequently, an assessment of perceptuo-motor skills as a part of a talent development programme for measuring the potential of young table tennis players seems sensible (Girard & Millet, 2009; Limoochi, 2006; Vandorpe et al., 2012).

From this perspective, the Netherlands Table Tennis Association proposed a perceptuo-motor skills assessment (Netherlands Table Tennis Association, 2011). This assessment intends to measure the potential of a young player (6-12 years) with regard to the perceptuo-motor domain, by assessing underlying perceptuo-motor skills for table tennis without using already trained authentic table tennis tasks (Faber, Nijhuis-Van der Sanden, Elferink-Gemser, & Oosterveld, 2014b; Faber, Elferink-Gemser, Oosterveld, & Nijhuis-Van der Sanden, 2014c). Assessing these underlying perceptuo-motor skills is suggested to represent a player’s future potential better than specific sport skills themselves, which depend on exposure to the sport itself, table tennis in this case (Faber et al., 2014a, Faber et al., 2014b, Gagne, 2004; Morrow, Jackson, Disch, & Mood, 2011; Vaeyens et al., 2008; Vandorpe et al., 2012). At this moment, the reproducibility of all test items is confirmed and the internal consistency and validity have good prospects (Faber et al., 2014b; Faber et al., 2014c). Still, an evaluation of the perceptuo-motor skills assessment concerning its predictive validity is essential for talent development purposes (Gagné, 2004; Vaeyens et al., 2008). The predictive validity should include both future competition participation and future competition performance for those who started playing official competitions. As a result, this study focuses on the following research questions:

1. Can the outcomes of the perceptuo-motor skills assessment predict future competition participation in young table tennis players?
2. Can the outcomes of the perceptuo-motor skills assessment predict future competition performance in young table tennis players?

It is hypothesized that the perceptuo-motor skills assessment outcomes predict both the possibility that children will start competition participation and the competition performance within the official competition. We set out to test the perceptuo-motor potential to become excellent table tennis players by using untrained perceptuo-motor tasks to avoid the influence of differences in table tennis experiences. Players who have better perceptuo-motor skills are suggested to be more motivated to start participation in competition and perform better during competition. Nevertheless, as other factors such as the influence of parents, the presence of local training facilities and coaches, and the availability and level of team-members are also considered to have a high impact on the table tennis performance level and the decision to participate, it is not known to what extent the percep-
tuo-motor skills outcomes can predict either competition participation and competition performance (McCullagh, Matzkanin, Shaw, & Maldonado, 1993).

Material and methods

Ethics Statement
This study and its informed consent procedure were approved by the ethical committee of the Medical Spectrum Twente (Medical School Twente, Institute for Applied Sciences, Enschede, the Netherlands; MTC/11069.oos 18-2-2011) in full compliance with the declaration of Helsinki. Written parental informed consent and players’ consent were obtained prior to the testing. Furthermore, both the children and their parents have given written informed consent, as outlined in the PLOS consent form, to publication of the pictures (S1 File).

Study design
An observational prospective design was used to evaluate the predictive validity of a perceptuo-motor skills assessment in young table tennis players, aged 7-11, concerning competition participation and performance outcomes. After the perceptuo-motor skills assessment, players’ competition participation and performance were monitored during five consecutive competition periods of six months.

Players
Young table tennis players were recruited on the regional talent day of the eastern department of the Netherlands Table Tennis Association in 2011 and 2012. The eastern department is one of eight regional competition departments connected to the Netherlands Table Tennis Association. Table tennis club members of the youngest age category (≤ 11 years) present during the regional talent day were selected and registered for these events by the trainers or coaches of their local clubs. The trainers and coaches were instructed to invite the youth members of their table tennis club with the highest potential for regional and/or national elite table tennis regarding both physical and mental aspects. These players needed to be under the age of 11. The eastern department’s total population of young players was estimated to be between 100 and 120 players per year. Players with injuries were excluded from the study.

Motor Skills Assessment
The perceptuo-motor skills assessment of the Netherlands Table Tennis Association consists of eight test items (Faber et al., 2014b; Faber et al., 2014c). The standardization of the test items is captured in protocols, which includes a detailed description of materials, set-up, assignment, demonstration, training phase, testing phase and registering test scores (S1 File) (Faber et al., 2014a; Faber et al., 2014b; Faber et al., 2014c; Netherlands Table Tennis Association, 2011).

‘Sprint’ included a pyramid-shape circuit in which players need to gather and return five table tennis balls one by one as fast as possible from five different baskets starting at the
basis of the pyramid-shaped circuit. Time was measured in seconds and the best of two attempts was used as the final score. For ‘agility’, players needed to get through a circuit, including climbing over a gymnastics’ cabinet (five times) and under and over a low hurdle (four times), as fast as possible. Players had one attempt in which time was measured in seconds. At ‘vertical jump’ players were instructed to stand next to a wall and jump and touch the wall with their fingertips as high as possible. The difference between the jumping height and standing height with one arm up along the wall was measured in centimetres. The best of three attempts was used as final score. ‘Speed while dribbling’ used a zigzag circuit in which the players needed to move sideways as fast as possible while dribbling with a basketball using one hand. Players had one attempt in which time was measured in seconds. At ‘aiming at target’ players needed to hit a round target (Ø 60 cm) on the floor at 2.5 meter distance with a table tennis ball using a standard bat with their preferred hand. Forehand and backhand had to be used alternately during the attempts. A hit in the target’ centre (Ø 0.20 m) or the outer ring yielded 6 and 4 points, respectively. The total score of ten attempts was registered as the final score. ‘Balls skills’ also required hitting a round target on the floor (Ø 75 cm), but now players needed to throw a table tennis ball with their preferred hand via a vertical table tennis table from two different positions (1 and 2 meter distance away from the target). Each player had a total of twenty attempts. A hit in the centre (Ø 0.335 m) or the outer ring of the target yielded 2 and 1 points, respectively. The total score of the twenty attempts was registered as the final score. At ‘throwing a ball’, the players threw a table tennis ball as far away as possible with their preferred hand. The distance from the starting-point at the marked line to the point of the ball’s first bounce was measured in meters. The best of three attempts was used as final score. In the ‘eye-hand coordination’ test players were instructed to throw a ball at a vertical table tennis table at 1 meter distance with one hand and to catch the ball correctly with the other hand as frequently as possible in 30 seconds. The number of correct catches was scored. The complete test protocol of the perceptuo-motor skills assessment is available (S1 File). To obtain a total score for the perceptuo-motor skills assessment, raw test scores were first converted into percentile scores per test item in coherence with the previous study. The total score is computed by summing up the percentile scores of all eight test items (range 0-800 points) (Faber et al., 2014b).

An initial evaluation of the perceptuo-motor skills assessment demonstrated fair to good reproducibility with regard to the level of test items, except for two test items: ‘aiming at target’ and ‘ball skills’ (Faber et al., 2014b). The internal consistency of all test items was satisfactory, and the principal component analyses revealed two underlying dimensions; ‘ball control’ and ‘gross motor function’. On the first factor ‘ball control’, high loadings (>0.65) were found for ‘speed while dribbling’, ‘aiming at target’, ‘ball skills’, ‘throwing a ball’ and ‘eye-hand coordination’. On the second factor ‘gross motor function’, high loadings (>0.65) were found for ‘sprint’, ‘agility’, and ‘vertical jump’ (Faber et al., 2014b). As expected, there were moderate but significant relationships between the perceptuo-motor skills assessment’s total score and the national ranking for boys and girls (6-10 years) at the moment of testing (Faber et al., 2014b). A revision of the test items ‘aiming at target’ and ‘ball skills’ en-
sured reproducible test scores, which also discriminated between high and low performers in young table tennis players (Faber et al., 2014c). Consequently, both revised test items replaced the original test items in the perceptuo-motor skills assessment.

Since the perceptuo-motor skills assessment included two revised test items, the reproducibility of the total score was evaluated as a part of this study using a test-retest design (n = 53) with the internal consistency being determined on the basis of the results of the initial test (n = 53). The intraclass correlation coefficient (ICC; two-way random model (type consistency; single measurement outcome) of the total score (0.91; p < 0.001) and the lower boundaries of the 95% confidence interval (0.90) met the criteria of >0.81 (p < 0.05) for reliability (Hopkins, 2000). The smallest detectable difference (SDD), and coefficient of variation (CV), used as agreement parameters (De Vet, Terwee, Knol, & Bouter, 2006), valued 98 points and 7%, respectively. Cronbach’s alpha was calculated at 0.82 including all test items, which meets the criteria of 0.8 for good internal consistency (George & Mallery, 2003).

All players were assessed under similar conditions at a local training centre during a regional talent day. Before starting the assessments, all participants did a warming-up as a part of the event. The testers were students of physiotherapy or table tennis trainers trained to the same degree with regard to using the test protocols; they were familiarized with the test protocol. Additionally, instructions and feedback were given during a training session by an expert-trainer of the Netherlands Table Tennis Association. The participants’ characteristics of height, weight and current training hours per week, as well as the control variables of sex, age, and training experience in months were extracted from the register forms.

**Competition participation and performance**

In the Netherlands, youth players can participate in the official competition of the Netherlands Table Tennis Association. This is a team competition and uses a hierarchical structure including both the national leagues and the regional leagues of eight departments. The highest national and regional leagues consist of only one group of teams. The other leagues contain more groups. In one calendar year, two competition periods are included, the autumn and the spring period, with 10 team matches each. Teams participating in the competitions consist of at least three players. Each team match contains nine individual matches in which three team members play against three players of the opponent one by one (i.e. three individual matches per player). Furthermore, two members of each team compete at the double-match. Each match won counts for one point, so a maximum score of 10 points can be obtained by a team per team match. The team with the most point in a competition period becomes champion of its league’s group and will be promoted to the subsequent higher league for the next competition period. Champions of the highest regional league will promote to the lowest national league in this case.

Competition participation and competition performance were provided by the Netherlands Table Tennis Association. Competition participation was considered nominal data (yes/no). A ‘yes’ was recorded when a player participated in an official competition of the Netherlands Table Tennis Association in at least one of the five consecutive competition periods of 6 months each after the regional talent day. Otherwise a ‘no’ was recorded.
The competition scores (points) of the five consecutive competition periods after the perceptuo-motor skills assessment were used as competition performance outcome. These competition scores per period are composite scores based on a player’s competition level and the percentage of matches he or she won during that period (Netherlands Table Tennis Association, 2013). The calculation of the period’s competition score is based on the official Netherlands Table Tennis Association’s national and regional competitions and can be converted to international standards. All leagues of the regional and national competitions for both youth and adult players and male and female players are compared in this one system taking strength differences between the existing leagues of the official competition of the Netherlands Table Tennis Association into account. As such, a player’s table tennis performance is ranked within a certain competition period compared to all players competing in different leagues.

Statistical analysis
 IBM SPSS Statistics 21 (IBM Corp., Armonk, New York, United States of America) was used for the statistical analyses. The normality of data was evaluated by comparing (1) means and medians of the test items and (2) standard deviation and ranges. Sample characteristics and descriptive statistics of the raw test item scores and the total score, including means, standard deviations, and ranges, are presented for the total group and split up for non-competition and competition players. The influences of sex and age on the total score of the perceptuo-motor skills assessment were tested to reveal the necessity to include them as covariates using a univariable general linear model (GLM) analysis. Moreover, competition performances were reported by presenting the players’ individual competition score curve during the two-and-a-half-year follow-up.

Then firstly, logistic regression analyses including the raw scores of the perceptuo-motor skills assessment items were used to examine if their outcomes predicted whether or not young players participated in the table tennis competition within the measurement period of this study. Secondly, a generalized estimating equations (GEE) analysis was conducted to explore the predictive value of the perceptuo-motor skills assessment items for the longitudinal competition outcomes of five competition periods in univariable and multivariable models (backward procedure). Test age (years), sex, and training experience (months) were included as covariates in both the logistic and GEE analyses. Alpha was set at 0.05 for significance for all analyses.
Results

A total of 48 young table tennis players (7-11 years) participated in this study; 25 from the regional talent day in 2011 and 23 from the regional talent day in 2012. This number amounts to approximately 20-25% of the players available in this age category in the eastern department per year. The sample characteristics and descriptive results of the perceptuo-motor skills assessment and covariates are presented in Table 1 and 2, respectively. All raw scores and the total score of the motor skills assessment for the total group were evaluated as normally distributed; means and medians were similar and the range around the mean followed a normal distribution. There were no missing data. The univariable GLM analysis for the total score demonstrated significant main effects of sex (F=5.479, p=0.024) and test age (F=3.954, p=0.008). Boys tended to perform better than girls on the test items, and older players had better scores than younger players. As such, sex and test age were depicted as covariates. No interaction effects were found.

Table 1. Characteristics of participants

<table>
<thead>
<tr>
<th>Participants (n)</th>
<th>TOTAL GROUP</th>
<th>NON COMPETITION</th>
<th>COMPETITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>48</td>
<td>9</td>
<td>39</td>
</tr>
<tr>
<td>2011</td>
<td>25</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>2012</td>
<td>23</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Sex (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>24</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Boys</td>
<td>24</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Test-age (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 years</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>8 years</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>9 years</td>
<td>20</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>10 years</td>
<td>17</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>11 years</td>
<td>7</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>M (range)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test age (y)</td>
<td>9.3 (7-11)</td>
<td>9.1 (8-11)</td>
<td>9.4 (7-11)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>143 (126-161)</td>
<td>142 (129-156)</td>
<td>143 (126-143)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>35 (22-57)</td>
<td>35 (26-57)</td>
<td>35 (22-56)</td>
</tr>
<tr>
<td>Training experience (months)</td>
<td>13 (1-48)</td>
<td>4 (1-6)</td>
<td>13 (2-36)</td>
</tr>
<tr>
<td>Current training (hours / week)</td>
<td>2.7 (1-7)</td>
<td>1.9 (1-3)</td>
<td>2.5 (1-7)</td>
</tr>
</tbody>
</table>

n=number; M=mean
### Table 2. Descriptive statistics perceptuo-motor skills assessment and logistic regression competition participation

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>TOTAL (n=48)</th>
<th>NON COMPETITION (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Sprint (s)</td>
<td>35</td>
<td>3.4</td>
</tr>
<tr>
<td>Agility (s)</td>
<td>25</td>
<td>4.5</td>
</tr>
<tr>
<td>Vertical jump (cm)</td>
<td>31</td>
<td>5.6</td>
</tr>
<tr>
<td>Speed while dribbling (s)</td>
<td>24</td>
<td>6.3</td>
</tr>
<tr>
<td>Aiming at target (points)</td>
<td>22</td>
<td>9.8</td>
</tr>
<tr>
<td>Ball skills (points)</td>
<td>19</td>
<td>6.4</td>
</tr>
<tr>
<td>Throwing a ball (m)</td>
<td>9</td>
<td>1.4</td>
</tr>
<tr>
<td>Eye-hand coordination (points)</td>
<td>13</td>
<td>7.0</td>
</tr>
<tr>
<td>Total score (percentiles)</td>
<td>466</td>
<td>143</td>
</tr>
<tr>
<td>Age at test moment (y)</td>
<td>9.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Sex</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Training experience (months)</td>
<td>11</td>
<td>9.0</td>
</tr>
</tbody>
</table>

*n = number, M = mean, SD = standard deviation, B = regression coefficient, SE = standard error, OR = odds ratio, CI = confidence interval, *p<0.05.*
<table>
<thead>
<tr>
<th>COMPETITION (n=39)</th>
<th>LOGISTIC REGRESSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>35</td>
<td>3.6</td>
</tr>
<tr>
<td>25</td>
<td>4.6</td>
</tr>
<tr>
<td>31</td>
<td>5.9</td>
</tr>
<tr>
<td>24</td>
<td>6.6</td>
</tr>
<tr>
<td>23</td>
<td>10.3</td>
</tr>
<tr>
<td>19</td>
<td>6.0</td>
</tr>
<tr>
<td>9</td>
<td>1.5</td>
</tr>
<tr>
<td>13</td>
<td>7.5</td>
</tr>
<tr>
<td>481</td>
<td>147</td>
</tr>
<tr>
<td>9.4</td>
<td>1.1</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>9.1</td>
</tr>
</tbody>
</table>
Figure 1 presents the competition score curve per player during the five consecutive competition periods after the perceptuo-motor skills assessment (n=39). Nine players did not enter the competition during the two-and-a-half-year follow-up or before this study was conducted. Most competition players participated in all five consecutive competitions after the regional talent day (n=25). The other competition players did not participate in all the competition periods (four periods n=6, three periods n=2, two periods n=2, one period n=4). The competition curves show that, in general, players tend to improve during the competition periods. Additionally, it shows that younger players (test age 7-8 years) have lower scores than their older counterparts (test age 9-11 years). All data obtained are available (S2 File).

![Competition score curve per player over five competition periods (≈2.5 years). Lines represent the individual players.](image-url)
Univariable logistic regression analyses to show whether the assessment’s results predicted competition participation within the measurement period of this study demonstrated no significant predictors; all regression coefficients show p>0.05 with the odds ratio 95% confidence intervals including 0 (n=48; Table 2). Moreover, the differences between the means of the non-competition (n=9) and competition players (n =39) at the individual test items (Table 2) were generally smaller than the standard error of the measurements of the items found in the previous studies focusing on reproducibility (Faber et al., 2014b; Faber et al., 2014c). Only the covariate training experience presented to be a significant predictor for future competition participation (p=0.012). This implies that players with more training experience at the moment of testing are more likely to join competition in the future. Since no other univariable models were found, multivariable models are not proposed.

The data of 39 young competition players could be included in the GEE analyses (Table 3). All perceptuo-motor skills assessment’s test items except one (agility), test age, and training experience predicted significantly the longitudinal competition outcome in univariable models (p<0.001). The best fitting multivariable model using a backward procedure (R²=51%) included the test items: aiming at target, throwing a ball, and eye-hand coordination. Although test age did not have a significant contribution to this best fitting model, inclusion was proposed as this factor showed to be a possible confounder in this study and to have influenced the item scores in previous studies Faber et al., 2014a; Faber et al., 2014b; Faber et al., 2014c). Consequently, another multivariable model was suggested for improved estimations of the test items’ regression coefficients. This model explained 53% of the variance of the longitudinal competition results, including 5 competition periods in 2.5 years.

**Table 3. Predictive validity results for competition performance (univariable and multivariable generalized estimated equations analyses, n=39)**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>B (SE)</th>
<th>Univariate</th>
<th>Best fitting</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td></td>
<td></td>
<td>-175,597** (46,50)</td>
<td>-93,588 (66,29)</td>
</tr>
<tr>
<td>Sprint</td>
<td>-10.109** (2.30)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Agility</td>
<td>-6.055 (3.92)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vertical jump</td>
<td>4.401** (1.08)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Speed while dribbling</td>
<td>-6.854** (1.33)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aiming at target</td>
<td>4.642** (0.92)</td>
<td>2.169* (0.89)</td>
<td>2.010** (0.82)</td>
<td></td>
</tr>
<tr>
<td>Ball skills</td>
<td>6.535** (1.22)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Throwing a ball</td>
<td>35.255** (4.99)</td>
<td>14.554** (5.61)</td>
<td>19.562** (5.71)</td>
<td></td>
</tr>
<tr>
<td>Eye-hand coordination</td>
<td>7.300** (0.86)</td>
<td>4.787** (1.04)</td>
<td>5.510** (1.08)</td>
<td></td>
</tr>
<tr>
<td>Age at test moment</td>
<td>3.103** (0.59)</td>
<td>-</td>
<td>-1.123 (0.66)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>38.357 (22.97)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Training experience</td>
<td>2.584** (0.60)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>51%</td>
<td>53%</td>
<td></td>
</tr>
</tbody>
</table>

*B=regression coefficient, SE=standard error, * p<0.05, ** p<0.01
Discussion

This study focused on the capacity of the perceptuo-motor skills assessment in young table tennis players (7-11 years) to predict future competition participation and competition performance over a period of two-and-a-half year. The results of this study demonstrated that the perceptuo-motor skills assessment outcomes did not predict competition participation within the measurement period of five competitions after the assessment. Competition participation might be better explained by other factors than perceptuo-motor skills, e.g. motivation, parental influences, training facilities, and the availability and level of team members, as proposed in the introduction (McCullagh et al., 1993).

Nevertheless, the results did indicate that the assessment of underlying perceptuo-motor skills may be an important predictor for future competition performance in young competition players (7-11 years) of the regional talent day over a period of 2.5 years. Based on our previous research, it even seems that future competition performance is better explained by the perceptuo-motor skills assessment than table tennis performance at the moment of testing (Faber et al., 2014b). The explained variance shown in the current study for the prediction of the longitudinal competition results ($R^2=51-53\%$) is higher than those presented in the previous study for the association between the perceptuo-motor skills assessment and national ranking at the moment of testing (boys $R^2=29\%$, girls $R^2=17\%$, 6-10 years) (Faber et al., 2014b). This supports the idea that the underlying perceptuo-motor skills reflect the potential of young table tennis players, but also that other factors are of influence (Faber et al., 2012). Moreover, it needs to be taken into account that competition scores are used as performance outcomes in this study and ranking position was used in the previous study (Faber et al., 2014b). Nevertheless, based on the results of this study, the perceptuo-motor skills assessment seems a suitable instrument as a part of talent development programmes including selection procedures and the monitoring of young players.

To our knowledge, there are no recent prospective studies, which include perceptuo-motor skills to predict table tennis sport performance. In other racquet sports, only two studies were found on this topic. Elliott, Ackland, Blanksby, & Bloomfield (1990) and Panjan, Sarbon, & Filipčič (2010) used an observational design to predict tennis performance from anthropometric, physiological and perceptuo-motor indicators. Comparable to our results, perceptuo-motor test items were considered the best predictors for performance. However, the predictive value in these studies was difficult to determine. Elliott et al. (1990) included only group comparisons regarding playing level at different age groups (11, 13 and 15 years). No prediction models were presented for future performance. Moreover, the accuracies of Panjan et al.’s models (2010) for the competition performance at the age category of 12-16 and over the age of 16, based on both the assessment under the age of 12 and 12-16 years, respectively, were poor with high relative absolute errors (0.59-0.99). Consequently, this study is one of the first attempts at forecasting performance curves in table tennis or other racquet sports on the basis of perceptuo-motor skills showing significant predictors.
The results of the current study correspond with the findings of Vandorpe et al. (2013). Their study included young gymnasts (7-8 years), in which the potential to become an elite gymnast was also considered to depend on perceptuo-motor skills. Vandorpe et al. (2013) showed that non sport-specific perceptuo-motor tests were significant predictors for performance results in young elite gymnasts, explaining more than 40% of the competition outcome two years later. In this study, the ‘Körperkoordinations Test für Kinder’ was used to measure general perceptuo-motor skills in children. The test items of this test battery appeal to a great extent on a child’s ability to maintain balance in dynamic situations, which is in line with the specific demands of gymnastics. In a parallel line, the test items ‘aiming at target’, ‘throwing a ball’ and ‘eye hand coordination’ used in the current study appeal to the players’ ability to control a ball (Faber et al., 2014b), which is a specific requirement for table tennis. Moreover, the study of Pion et al. (2015) revealed that tests assessing perceptuo-motor skills, which were non-specific to volleyball, discriminated between elite and sub elite adolescent volleyball players (p < 0.036). The authors conclude that volleyball as a skill-based sport requires a well-developed level of perceptuo-motor skills (Pion et al., 2015). Consequently, it is suggested that perceptuo-motor skills indeed play an important role in the development of young athletes’ performance level in sports consisting of complex motor tasks. Yet, specific tests to assess the underlying skills inherent to a particular sport seem appropriate.

Although the relation between perceptuo-motor skills and future performance is highlighted by the current study and earlier results (Elliot et al., 1990; Panjan et al., 2010; Van Dorpe et al., 2013), the multidimensionality of talent development must be taken into account (Elferink-Gemser et al., 2011). The perceptuo-motor skills assessment only measures potential in the perceptuo-motor domain. The variance of the competition outcomes that could not be explained is probably due to other factors. Mental aspects, like motivation, self-efficacy, volition, and self-esteem, and contextual factors, such as training facilities and parental support, are hypothesized to have a substantial influence on performance outcome (Gillet, Berjot, & Gobancé, 2009; Lane, Jones, & Stevens, 2002). This probably also accounts for the prediction of future competition participation. As hypothesized, personal or contextual factors other than perceptuo-motor skills seem more important to young players and their parents to decide to participate in competitions. Therefore, the perceptuo-motor skills assessment as a part of a talent development programme, should be accompanied by an evaluation and monitoring of other critical factors.

Some limitations of this study need to be acknowledged. First of all, this study included a small sample recruited during the regional talent day and already selected by club trainers. Although the perceptuo-motor skills assessment is used during regional talent days, the generalisation of the findings to the players on the national talent day, including players from other regions, is worth discussing. Since no ceiling effect seems to exist with regard to the test item scores, the total score, and the competition outcomes in this study and sufficient variety in the scores is expected between players participating in the national talent day, it is hypothesized that generalization is possible. The predictive validity should
be studied in a larger sample, including players from the national talent day to verify this hypothesis. The assessment might lose its strength in a small homogenous sample regarding perceptuo-motor skills, e.g. the national top 10 players. Evaluating other factors such as motivation, trainability, and mental aspects might be more sensible in such context. Secondly, only a relatively short follow-up of 2.5 years was realised in this study. This implies that the perceptuo-motor skills assessment’s results are used to predict performance results still at a relative young age. Although, significant predictors were found, these results do not guarantee the predictive value of the perceptuo-motor skills assessment over a longer time period or in other age-ranges. A longer follow-up period is crucial for evaluating the solidness of the predictors for adult success. The inclusion of repeated measurements to monitor the players’ development during the follow-up might improve prediction accuracy, as a longer period of time increases the interference of other factors. Thirdly, to optimize the power of this study, analyses were conducted using the total sample. Results from boys and girls within the test age spanning from 7 to 11 years were analysed all together. Consequently, the analyses included different developmental stages in which the associations were calculated, especially in considering influence of differences in growth and maturation [48]. Although sex and test age were included as covariates, it is recommended for future research to split the analyses for boys and girls as differences in predictors might exist and reduce the age span for prediction models.

In conclusion, we found that the predictive validity of the perceptuo-motor skills assessment has promising prospects. An instrument such as the perceptuo-motor skills assessment can objectify a young player’s potential and, for that reason, support selection decisions by coaches. It has to be emphasized, however, that talent development is a multidimensional process (Elferink-Gemser et al., 2011), and the perceptuo-motor skills assessment is suitable for being a part of a talent development programme. Moreover, to interpret individual player’s test scores, it is important that the player’s sex, test age, training experience, growth and maturity level are taken into account (Coelho ESilva et al., 2010; Malina, Cummings, Morano, Barron, & Miller, 2005). Furthermore, talent development programmes do not intend to limit the freedom of choice in children to practice a particular sport. Trainers and coaches should also be aware of the potential risks of early specialization and selection (e.g. injuries, mental exhaustion and drop-outs) (Baker, Côté, & Deakin, 2005; Wall & Côté, 2007). The perceptuo-motor skills assessment is only intended to identify those children excelling in the perceptuo-motor skills essential for table tennis. Finally, additional studies are needed to evaluate the predictive value in a larger sample over a longer period of time.
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Supporting Information Legends

S1 File. Test protocol perceptuo-motor skills assessment
S2 File. Full dataset


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Chapter 8


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Chapter 9

High potential in table tennis from the perspectives of elite players and their youth trainers: an explorative qualitative study

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CHAPTER 9

Abstract

Many table tennis associations use talent development programmes to identify young high potential players and to support children intending to become elite players. However, identifying young children with the potential of becoming elite players is a challenge as the key factors for future success remain ambiguous. An extensive determination of the nature of high potential for table tennis is suggested to provide a better understanding of these success factors. The experiences, perceptions and ‘hidden’ knowledge of players who succeeded and became world-class elite players and of their youth trainers can be helpful to unravel this mystery. Consequently, the aim of this explorative qualitative study was to get grip on what is meant by ‘high potential’ for elite table tennis from the perspectives of elite players (World Ranking top 20) and the trainers of their formative years. Semi-structured in-depth interviews were conducted to uncover the multi-dimensional concept of ‘high potential’. After transcribing the interviews, open and axial coding were carried out using an inductive approach. The results presented seven interrelated categories: early exposure, deliberate play, fit to table tennis, learn fast, taking the next step, constant competition and reaching the top of the world. Each category demonstrated that ‘high potential’ for elite table tennis can only be described with reference to the three elements: the player, the task table tennis and the environment. This is consistent with the ecological-dynamic approach. In addition, it is proposed that ‘development’ should be inserted as a fourth element since the other elements continuously change over time. The perspectives of the elite players and trainers presented in this study give direction to further studies focusing on the concept of ‘high potential’ for elite table tennis and to ways of assessing or monitoring this in young table tennis players.

Keywords: table tennis, racquet sports, aptitude, gifted children
Introduction

Many table tennis associations use talent development programmes to identify young high potential players (<12 years) and to support those aiming to become elite players. Selection criteria to participate in such programmes are often based on trainer’s judgements of performance results and observations during training and competition. However, the ranking positions of performance under the age of 14, 18 and 21 have proven to be poor indicators for future success in racquet sports (Brouwers, De Bosscher, & Sotiriadou, 2012; Heller, 2008; Reid, Crespo, Santilli, Miley, & Dimmock, 2007). Moreover, the judgments and observations of trainers are often intuitive, based on experiences and not transparent to others. It is probably for that reason, why other solutions are sought for assessing a young player’s potential.

Several studies in table tennis and other racquet sports tried to find indicators in a player, other than performance at a young age, to measure the potential to become an elite player. Most of these studies used a cross-sectional design to compare elite versus non elite players regarding various aspects (Barikosz, 2012; Blomqvist, Luhtanen, Laakso, & Keskinen, 2000; Faber, Oosterveld, & Nijhuis-Van der Sanden, 2014; Landlinger, Stöggl, Lindinger, Wagner, & Müller, 2010) or to associate test results of different constructs to performance outcome at the same point in time (Filipčič, Pisk, & Filipčič, 2010; Girard & Millet, 2009; Karnia et al., 2010; Lane, Jones, & Stevens, 2002; Ziemann, Sledziewska, Grzywacz, Gibson, & Wierzbka, 2011). The profiles of elite players at a certain age can be derived from these studies. Nevertheless, if the aim is to measure the potential of young players (<12 years) and predict future performance, a longitudinal design is crucial (Vaeyens, Lenoir, Williams, & Philippaerts, 2008). Only a design like this allows verifying whether a test result or trainer’s judgment is able to forecast future high performance, and so is measuring the potential of a young player (<12 years) to become an elite player.

A systematic search in five databases (PubMed, PsychINFO, Web of Knowledge, ScienceDirect, and SPORTDiscus; 1990-2014) yielded only three articles regarding players’ potential for high performance in racquet sports including a longitudinal design (Faber, Bustin, Oosterveld, Elferink-Gemser, & Nijhuis-Van der Sanden, 2016). Anthropometric measurements to measure physical appearance, perceptuo-motor tests for measuring speed, agility and coordination, and questionnaires to get insight into a player’s motivation, and self-efficacy were evaluated in these studies as determinants for success (Elliot, Ackland, Blanksby, & Bloomfield, 1990; Gillet, Berjot, & Gobancé, 2009; Panjan, Sarabon, & Filipčič, 2010). Although, Elliott et al. (1990) and Panjan et al. (2010) proposed height, speed/agility and coordination tests for future success in tennis based on their results, it was impossible to determine the predictive value of these indicators for the long-term. Elliot et al. (1990) included only group comparisons regarding playing level at different age groups (11, 13 and 15 years) with a relatively short follow-up (4 years). Differences in growth and maturity can provide temporary advantages, which may disappear after puberty (Pearson, Naugh-
Moreover, the accuracies of Panjan et al.'s models (2010) were poor with high relative absolute errors (0.59-0.99). Gillet et al. (2009) showed that self-determined motivation was a significant and positive predictor for tennis performance during two years. Nevertheless, the inclusion of young players (13-14 years) together with the short follow-up and the low amount of explained variance reduce the predictive value for elite performance in adulthood. Thus, identifying young children (<12 years) with the potential of becoming elite players is a challenge as the key factors for future success remain ambiguous.

Besides the methodological limitations of previous studies (Elliott et al., 1990; Gillet et al., 2009; Panjan et al., 2010), another possible explanation for the difficulties in finding diamonds in the rough is that the concept of high potential in table tennis has not been determined yet. In addition, the assessment of potential is considered to require a multidimensional approach (Elferink-Gemser, Jordet, Coelho E Silva, & Visscher, 2011; Gagné, 2004). The previous studies mainly focused on factors in one or two domains and did not include a multidimensional model including environment influences to reflect potential. An extensive determination of the nature of potential for table tennis is suggested to be the next step to provide a better understanding of the predictors for success. The experiences, perceptions and ‘hidden’ knowledge of players who succeeded and became world-class elite players and of their youth trainers can be helpful to unravel this mystery. A qualitative, bottom-up approach is needed for this purpose (Faber, Nijhuis-Van der Sanden, & Oosterveld, 2012). Consequently, the aim of the current explorative qualitative study is to get grip on what is meant by ‘high potential’ for elite table tennis from the perspectives of elite players and the trainers of their formative years. The Consolidated Criteria for Reporting Qualitative Studies (COREQ) was used for reporting where possible (Tong, Sainsbury, & Craig, 2007).

Methods

Design
This explorative qualitative study included semi-structured in-depth interviews to unravel the multi-dimensional concept of ‘high potential’ in table tennis. An empirical phenomenological approach was used in which the participants’ perspectives on essential experiences were presented (Allen-Collinson, 2009). The study design, data collection and informed consent procedures were approved by the Research Ethics Committee Regio Arnhem-Nijmegen (Nijmegen, the Netherlands; 2014-1329).

Participant selection
Participants were selected on a theoretical basis. Since the research question focuses on high potential in table tennis, three elite players, who were ranked in the International Table Tennis Federation (ITTF) World Ranking top 20 (period 2000-2015), were sought. Additionally, as the players needed to share and reflect on their experiences throughout their table tennis career from youth through adulthood, only players ≥ 25 years were included (Kitsche-
ner, King, & De Luca, 2006). The elite players were asked to select one trainer, who had a prominent role during their sports career at a young age. All participants were approached by e-mail or telephone. None of the players or trainers refused to participate or dropped out. Written informed consent was obtained prior to the interviews.

**Interviewer**

The semi-structured interviews were conducted by IF* (physical therapist and movement scientist, MSc). At the time of the interviews, she was 35 years old and a researcher focusing on talent identification and development in table tennis. Moreover, she has been a player in national competition and a licensed table tennis trainer for approximately ten years. The interviewer followed a comprehensive training programme regarding qualitative research, including interview training. One of the elite players and one of the trainers knew the interviewer prior to the study from other research projects and training sessions, respectively.

**Data collection**

A narrative-based approach was used as an interview guide in which the development of the player from birth to world-class player was discussed. A topic guide, based on the literature, ensured the structure of the interview with open questions and an in-depth exploration of the concept of potential for elite table tennis based on the experiences and perceptions of the players and trainers. The interview guide and topic list were pilot-tested on former national players in field hockey (n=1) and basketball (n=1). Interviews were audio-taped and short notes about the player’s career time-line and specific characteristics mentioned by the player or trainer were taken by the interviewer. Interviews lasted approximately one hour each and no other persons than the participant and the interviewer were present. All players were interviewed at a table tennis training centre and the trainers at their homes. For one of the trainer interviews, a video call was used. A member check was conducted on a summary of the interview. As this study was explorative in nature, data saturation was not intended.

**Analysis**

Interviews were digitally recorded and transcribed verbatim. Subsequently, three data coders started independently with open coding. IF* coded both the players’ and trainers’ transcripts, PB* only the players’ transcripts and SH* only the trainers’ transcripts. After the independent coding, consensus was reached on the themes that were derived from the data. Consecutively, axial coding was carried out (inductive approach) in a peer debriefing including three sessions. The authors and an expert trainer of the Netherlands Table Tennis Association were involved in the first session. The second session was conducted by three movement scientists with no experiences in the field of talent development in table tennis under guidance of two of the coders (IF* and PB*). The third session involved only the coders. During the sessions, codes were related to each other by discussing the individual manuscripts until a final preliminary concept of potential for table tennis was established during the third session (Corbin & Strauss, 2014).
Results

Description of participant

All included players (n=3) and trainers (n=3) were male and of European descent. The mean age of the players and trainers was 40 years (SD 6) and 68 years (SD 6), respectively. All players were ranked between 1st and 20th position on the ITTF World Ranking at a point in time between 2000-2015. Two players had already retired for some years from their professional international table tennis career, which lasted almost twenty years. One player started his international career eighteen years ago and still plays at world events. At the time of the interview, he was ranked between the 1st and 20th position. The three trainers included in this study were licensed, had at least 30 years of experience and were still active as table tennis trainers.

The concept of potential

The coded fragments of all interviews were reduced to seven interrelated categories describing the perspectives of the elite players and trainers with regard to high potential for elite table tennis: early exposure, deliberate play, fit to table tennis, learn fast, taking the next step, constant competition and reaching the top of the world.

Early exposure

All players described that they were exposed to sports in general, and specifically table tennis, already at an early age (between 4 and 7). This ‘early exposure’ was implicitly initiated by their parents and/or other family members as playing table tennis was part of the ‘family culture’. Although the interviewed trainers were not involved with the players at this early age, they recognized this early exposure during the development of other players who reached elite or sub elite level.

Quote 1:

‘My sisters played table tennis. My father trained them and I just tagged along.’

Especially the fathers were experienced as role-models for the young boys becoming interested in sports. This was mentioned by both the players and trainers. Fathers were described as sport-minded and participated actively in table tennis as players and/or trainers. Moreover, they ensured a stimulating environment by, for example, putting up challenges and purchasing a table tennis table to be able to play at home.

Quote 2:

‘I think, especially my father was really into sports. He also played table tennis a little, not at a high level, but he liked sports. Soccer. He was also a goalkeeper in the soccer team when he was young and then he started getting some physical problems and switched to table tennis. In 1985, he bought a table tennis table.’
Deliberate play

During the first explorations in sport, the elite players remembered their ‘deliberate play’, which is characterized by continuous and creative play and the enjoyment felt during non-predefined exercises. They invented all kinds of games alone or together with their family and/or friends to challenge themselves. They felt an intense urge to move and play while encouraged by their success experiences and environment.

Quote 3:
'I tend to think.... You know, it started ... When I was about four years old. Or ... Not really play table tennis, but it started with a ball on a bat. And then ... My father made me, not crazy, but more like: 'When I get home, I’m wondering if he can do it ten times.’ Then I started to practise. Then it was ‘hop’,... and then with the ball and bat climbing up the stairs and down the stairs. Just against the wall. Just without bouncing. How often can you do that? So I did all kinds of exercises. It was just great fun doing that.’

One player pointed out his sport-mindedness for all sports and how he integrated sports in his daily playing activities during childhood.

Quote 4:
'When Wimbledon was on television, well, I went outside with a boy next door, found two broomsticks... just on the street. There was a curb, the field and then we drew the service line, back line, two broomsticks and a rope. If a car came along, we quickly put our broomsticks to the side. We played tennis there with a softball. He was a good tennis player. Usually ... I don’t remember if I ever lost, I can’t tell. But he played tennis in the selection, and then we replayed the whole Wimbledon tournament. We used to play tennis all afternoon. And when it was the cycling season, the boys in the neighbourhood and I went cycling like hundred laps or so. Just through the streets. You just got totally caught up.’

Deliberate play is mainly mentioned as an aspect in the early development by the players but continued when practising at a club started (<13 years). The trainers recognized this as the players loved to fill all of their spare-time with self-made games related to table tennis. With deliberate play, the players and trainers believed to start developing the first essential principals for a sustainable sport development. The playing is suggested to lead to motor-learning, success experiences, self-efficacy and consequently to a reinforcement to continue playing. The early skills developed seemed to distinguish the elite players from other children of their age (4-8 years) with respect to their general coordination and ball control. Deliberate play accounted for many hours of practise including many variations under different circumstances, but was typically not perceived as training by the elite players.
Fit to table tennis

Already at a young age (<10 years) it was clear to the elite players and trainers, that the elite players fitted very well to table tennis. This ‘fit to table tennis’ was described by their great performances compared to peers, their drive to excel at table tennis and the concomitant willingness and ability to train. This latter was represented by an insatiable hunger for training.

During their training and competition, they demonstrated strong ability with regard to coordination, timing, anticipation, ball control and technical aspects (strokes). It was described by one player as a sort of natural giftedness; he just did it in the right way (Quote 5c).

Quote 5a:
‘He (12 years old) had a tremendously good sense of movement, coordination, compared to other players, which I saw as a trainer. His movements were fluent, not truncated movements.’

Quote 5b:
‘He (9 years old) was very good at handling the ball. He could do anything I asked him to do. Backspin, side-spin, topspin, his abilities with the ball were infinite.’

Quote 5c:
‘When you are young (6-8 years old) you don’t make so many thoughts about how to do it, but you just do it and that was my advantage that I… just did it and it was correct. It was the right way how to do it. This is important, I think, when you are young. To improve. To be talented and I think, this is talent. If you don’t think about it so much and do it in the right way.’

Moreover, the players and trainers described the importance of the ability to ‘read the game’ at a young age. This was explained by them as the capacity of knowing what the player needs to do to win the game, the ability to have a solution, creativity and to foresee or anticipate on the tactics of their opponent. Also the ability to focus on the competition, and to maximize concentration for each point was appointed as a main factor of fitting the task.

Quote 6:
‘He (12 years old) could read a game very well. It is also one of the characteristics of the game. When comparing him to other leading players, who worked hard, harder than he did, so to speak, but they were less capable to read the game. To see what needed to be done. He had a much better overview of a game … Even at a young age.’

The high performance at a young age was not only noticed by the trainers, but was also reflected by the performance records. The elite players played competitions at a higher level than most peers of the same age. For example, they played in the highest national
senior competition at the age of 12-14 years. Nevertheless, none of the elite players or the trainers were fully convinced that they could have predicted future successes on world-class level as a senior player at this age. The elite players, at that age, just participated in those events that they qualified for. No ‘big plan’ focusing on winning a medallion at, for example, the Olympics had been made at that point in time. They clearly needed further education and guidance on technical, tactical, and mental aspects to reach the top of the world.

Learn fast

In addition to fitting to table tennis, the elite players and their trainers identified the ability to ‘learn fast’, i.e. better than above average, as a crucial factor to develop up to world class level. This included the player’s eagerness to learn, a balance between a task-oriented and result-oriented approach, self-reflection, and the ability to make essential improvements in their play.

**Quote 7:**

‘...but it is my strong conviction that I have a talent for learning. I do not have a specific talent for table tennis.’

The elite players only needed brief instructions and were able to select the specific information they needed for their personal improvement and integrated this quickly in their own play.

**Quote 8a:**

‘He could accomplish a lot with only few instructions.’

**Quote 8b:**

‘I think I rapidly understood what the trainer told me and was also able to do it. Not just understanding, but also doing it in the correct way. I didn’t need a long time to improve these things.’

During the early development phase and puberty (<16 years), learning was regarded as an implicit process; the elite players confirmed they used unconscious learning strategies. Deliberate play, as described above, is one example of such a strategy. About the age of 15-16, thoughts of what and how to improve became more explicit.

Although both the elite players and trainers generally illustrated how fast learning was presented by the elite players during their education, the interviews also revealed that trainers, training partners, parents, other environmental factors, and coincidence all played a role in making fast learning possible. Without the right preconditions in a specific phase, the learning process would probably be disturbed and delayed. Especially being guided by a capable trainer is essential. It was believed that when incorrectly learned skills needed to be unlearned as a consequence, for example, of poor guidance, this would have been at the expense of the development’s efficiency.
Quote 9:
‘...if you are educated by poor trainers during the early development phase, it will identified too late that you actually have potential. You know, to unlearn something is much harder than to learn something. That will play a role at that moment. Coincidence plays a role in that. Did you happen to be in the right place, that a trainer guides you what is best for you, and so on.’

Taking the next step
The elite players all went through a similar system of different playing levels. They first started at a local club and competed in regional competitions and tournaments. As performance results improved, they promoted to national events, international level and finally reached the top 20 in the International Table Tennis Federation's World Ranking. Such a pathway included many stages at which 'taking the next step' was necessary. Taking the next step should not only be regarded in this context as a consequence of, but also as a requirement for development.

Taking the next step at some points in the development meant that the elite players needed to be ready to compete at a higher level. At another stage, they needed to make specific choices to create the right conditions to establish improvement. Moreover, whether the elite players were able in to take the next step was not only a consequence of the player's capabilities or choices. It was also considered to be dependent on their environment, especially on being selected and guided by the 'right' trainer and being selected for specific teams and tournaments, to get the opportunity to fully develop their potential. With this, parental support and (their) financial resources should not be trivialized as influences on the ability to take the next step.

The enormous drive for table tennis, the extreme motivation to improve their play, perfectionism and the will to win have been put forward by the players and trainers as important fundamentals for the elite players to push boundaries and stepping out of their comfort zone.

Quote 10a:
‘Just the challenge to improve yourself and become a better player.’

Quote 10b:
‘This is the base of the sportsman. To be... That you want to win.’

As they felt responsible for their own development and performance, the elite players used self-reflection implicitly or explicitly to get insight into their personal strengths and weaknesses. Subsequently, they were able to set appropriate and achievable goals for which they knew exactly what was necessary to reach them. Setting goals was often done in cooperation with their trainers. During practice the elite players got out of their comfort zone and were strikingly capable in selecting those things they consi-
dered relevant for making improvements. As improvement took more and more when the playing level increased, a significant appeal was made on the perseverance, volition and mental toughness of the elite players from the age of 14-16.

Additionally, becoming a world’s top 20-player was considered to require full dedication and commitment to table tennis by both the elite players and the trainers. The elite players illustrated this by summing up several choices they made during their careers: quitting other sports activities (<10 years), transferring to other clubs for training and/or competitions (often at a considerable distance from their hometowns), neglecting and quitting school/education (14-18 years), moving in their homeland (17-18 years), changing lifestyle (nutrition and work-rest ratio) (>14 years), keeping up physical training (>15 years), and emigrating to another country (>18 years). Environmental influences (e.g. parental and trainer support) in making choices successfully differed between the elite players and changed over time in the players.

Quote 11:
‘I just always wanted to play table tennis, so ... Yeah, where can you do it better? I always played close to my homeland, because that was my home. There I had a decorated room. In Germany I had a room that I deliberately did not furnish, it was just ... a mattress on the floor. It had a bed and a kitchen, but I never made an effort to do it up. Deliberately. That was not my home. That was my table tennis.’

Constant competition
All interviews in this study showed that the elite players were in a sort of ‘constant competition’ during their development into a World Ranking top-20 player. They mostly searched for competitions while aspiring and enjoying the constant challenge. Due to this constant competition, the players felt the urge to improve themselves and the need to bring everything into play to connect with the better or the best players. Both the elite players and the trainers emphasized that it was crucial to play against the better and finally the best players to reach the highest level in table tennis.

Quote 12:
‘The environment is important. When it comes to table tennis, this means the competitions and/or training-partners. Without good sparring partners a player cannot achieve what it is he wants to achieve. This is already important from an early age.’

When the elite players entered the international level, they started comparing themselves to the top of the world and consequently got a fair representation of their own position. They tried to analyse their opponents to learn to beat them and learn how they could improve their own play by integrating the strengths of the opponents. Both were pointed out to be necessary to succeed at the world’s highest level.
Reaching the top of the world

Then naturally to ‘reach the top of the world’ and enter the top 20 of the ITTF’s World Ranking, winning at world-class events is essential. Both the elite players and trainers pointed out that it is important to be able to peak at such events and maintain this high-level performance during the entire length of the tournament. Their level of performance depended on the weakest link at that moment in time. The players and trainers interviewed described different kinds of reasons for a decrease in performance; not able to handle the physical, mental or emotional stress or the social pressure. Emotional stability, resilience, perseverance, the ability to ‘live in the moment’ and self-confidence were considered to be key factors for success.

Quote 14a:
‘I just played and even when I was younger and we drove to some tournament with my peers; they lost two nights’ sleep over the competition and once in the car I simply asked: ‘Where are we going?’”

Quote 14b:
‘He was able to totally concentrate on the next game during a competition. He just forgot everything else. Moreover, when the competition was finished, he was done.’

When philosophizing about how to become the world’s number 1, the players and trainers introduced a sort of ‘x-factor’, something that distinguishes a player from the others. This factor was described as a component of the player’s capability in performing table tennis. It was quite hard to find the right words to define this factor. Nevertheless, it became clear that it implied the ability to excel in gathering all information to ‘read their opponent’s game’ in a relatively short time, in creative solutions during the rallies and in the anticipation of the opponent’s returns. It seems like they foresee everything that will happen during a rally and bend things the way they suit them.
Discussion

The in-depth interviews from this study revealed that ‘high potential’ for elite table tennis can only be described with reference to the three elements: the player, the task of table tennis and the environment. This is in connection with the ecological-dynamic approach (Fig. 1) in which motor development is suggested to result from an interaction between the individual, task and environment (Newell, 1986; Shumway-Cook & Woollacott, 2007).

Moreover, based on our study, we propose that ‘development’ should be inserted as a fourth time-related element as the other elements continuously change over time. Probably this is in accordance with the model suggested by Elferink-Gemser & Visscher (2012), which includes the person-related, task-related and environmental characteristics and an arrow representing the development of sports performance over time. The text fragments of both the elite players and the trainers in this study illustrated that a player cannot be seen as an entity on his or her own account during the development from a novice to an expert table tennis player as he/she continuously interacts with a dynamic environment.

**Figure 1.** Movement emerges from an interaction between the individual, the task and the environment (Shumway-Cook & Woollacott, 2007).
Also, the demands of the task of table tennis change in the fullness of time as players develop to higher competition levels. It seems that the triangle, the player, the task and the environment, perfectly fitted to each other to create crucial opportunities during all phases in development of the elite players (Fig. 2).

![Figure 2. A model for the development of high performance in table tennis players. (T=task, P=player, E=environment.)](image)

From this perspective of high potential, distinguishing between the natural abilities (Gagné, 2004) of a young table tennis player and skills that were learned by training is difficult. This was reflected by the quotes of the elite players and trainers in which development was often described in its context. In coherence, Ackermann (2014) emphasized that both nature and nurture determinants along with their interactions will explain elite performance. Additionally, as mentioned in the introduction, high potential is suggested to be a multidimensional phenomenon (Elferink-Gemser et al., 2011). The different aspects of ‘high potential’ in a player reported by the elite players and trainers in this study confirm this point of view, which makes the concept of ‘high potential’ even more complex.

Since this study was explorative in nature only a preliminary concept of ‘high potential’ in table tennis is presented. Nevertheless, the seven categories derived from the codes were regarded as meaningful themes, which demonstrated noteworthy aspects of the elite players’ histories for everyone interested in talent development. Although there seems to
be some chronological relation between the categories, from early exposure to reaching the top of the world, seeking a relation here was not specifically intended. Deliberate play, for example can be something that a player likes and does during a great part of his career. Moreover, taking the next step starts at a young age and continues to the end. A better model of the concept of 'high potential' from the elite players’ and trainers’ perspectives can be proposed if data saturation is reached in a larger sample.

All interviews showed that the elite players presented a successful combination of physical, perceptuo-motor, technical, tactical, mental, emotional, self-regulative and learning abilities in a stimulating and adequate context fitted to the needs at that moment in time. These findings might create a foundation for specific multidimensional test instruments for talent development. Yet, it is important that it is realised that the pathways to success are individual (Phillips, Davids, Renshaw, & Portus, 2010). They depend on the player’s abilities, growth, maturation (Pearson, Naughton, & Torode, 2006), and learning and the opportunities (made) available in the environment over time.

The weakest link in a player or the context during development is considered to determine the final level of performance. Nevertheless, identifying something as the weakest link is difficult sometimes. For example, constant competition was suggested to be highly important to connect to the highest level. Two of the three players did not find this in their homeland and literally needed to cross borders. After they managed to do that, their native country with a low level of competition became a ‘land of opportunities’ as they were always selected to play international tournaments. Playing at the highest level made it possible to compete at the highest level.

It needs to be acknowledged that this study was conducted in western Europe. Although a qualitative approach is not intended to generalise result, but to present the richness of findings with respect to a certain phenomenon, the context of this study influences the findings. Other main themes might be derived from data collected in other parts of Europe or continents. Furthermore, as this study was intended as an initial exploration, data saturation was not reached. Additional interviews with female players and their trainers, for example, could enrich the data as new codes can possibly be identified.

In conclusion, the aim of this study was to explore 'high potential' in table tennis as perceived by three couples of elite players and their trainers. The qualitative approach led to the insight that the concept of ‘high potential’ can only be fully understood in the triangle of the player, the task and the environment and a fourth element, the dynamical changes over time. The multidimensional aspects derived from the interviews with the elite players and their trainers give direction to further studies focusing on the concept 'high potential' and ways of assessing or monitoring this in young table tennis players (Elferink et al., 2011; Faber et al., 2015).
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References


Chapter 10

General discussion

In conclusion, ...
**Determining high potential**

The main aim of this thesis was to gain insight into the concept of high potential for elite performance in table tennis by searching and assessing personal talent determinants in youth players (6-12 years). The results of the studies included in this thesis shine new lights on the finding of high potential in table tennis players. We found that it is possible to assess perceptuo-motor skills in youth table tennis players (≤ 10 years) in a reproducible way and that these scores have added value in the prediction of future table tennis performance. Additionally, the systematic review and qualitative study showed that also determinants of other domains than the perceptuo-motor domain should be taken into account. Accordingly, the first section of the general discussion focuses on the evaluation of the Netherlands Table Tennis Association’s (NTTA) perceptuo-motor skills assessment as a part of a talent development programme for table tennis. The second part attempts to provide a more specific concept of high potential in table tennis from a multidimensional perspective using Gagné’s Differentiated Model for Giftedness and Talent 2.0 (2010) as fundamental (Figure 1). Directions for future research are presented in the third part. Finally, this chapter closes with the conclusive remarks.

**The value of a perceptuo-motor skills assessment**

**Practical implementation**

As pointed out in the introduction, table tennis associations try to select high potential youth players already at an early age (≤ 10 years) (Limoochi, 2006). However, trainers or scouts estimate a youth player’s full potential using observations of current performance and performance outcomes. At such a young age, selections based on table tennis performance alone are influenced to a large extent by individual differences in growth, maturatio-n, development and learning curves, training experiences, competition participation and environmental factors. These factors can create temporary advantages or disadvantages at these young ages, but probably do not reflect a youth player’s full potential which hinders the interpretation of the observational findings (Brouwers, De Bosscher, & Sotiriadou, 2012; Malina et al., 2005; Reid, Crespo, Santilli, Miley, & D immock, 2007; Coelho E Silva et al., 2010).

The evaluation of the measurement properties of the Dutch perceptuo-motor skills assessment has presented good prospect for this assessment to be included in a talent development programme (chapter 4 to 8). The perceptuo-motor skills assessment can be of value for the estimation of potential regarding the perceptuo-motor domain, especially in youth players (≤ 10 years) with differences in quantity and quality regarding their training and competition experience in table tennis. The outcomes of the assessment can support the decision of trainers or coaches to select a player for a specific training programme. Currently, the Dutch perceptuo-motor skills assessment is used at the national and regional talent days of the Netherlands Table Tennis Association. Although, the observational
study (1998-2013) in chapter 4 revealed that the assessment has predictive value for the
table tennis performance of the youth players assessed at the national talent day, the re-
results of chapter 8 indicate that the predictive value is even better for the youth players of
the regional talent day. Nevertheless, this assumption should be taken with caution as the
assessments and the time periods were not identical.

It is important to mention that until now the assessment has only been used to measure
the player’s perceptuo-motor skills once at a young age. We expect that for the estimation
of a player’s potential might benefit from repeated measures over time as this is suggested
to give a better indication of a player’s development and learning curve (Ackerman, 1998;
Ericsson, Krampe, Tesch-Römer, 1993; Gagné 2008; Huijgen, Elferink-Gemser, Post, & Viss-
scher, 2009). From our studies and field experiences, we can conclude that the test items
are useful for players within the age range from 8 to 10 or 12 years. Nevertheless, future
studies must reveal whether all test items are also valid for using them in younger and older
youth players to monitor their potential for the perceptuo-motor domain. Only the test items
insensitive to bottom or ceiling effects in the test scores and with the ability to discriminate
and predict will be of value.

In addition, since the determination of a youth player’s potential is acknowledged to be mul-
tidimensional (Elferink-Gemser, Jordet, Coelho E Silva, & Visscher, 2011), the assessment
should be completed with other criteria for selection, e.g. motivation, trainability, learning
ability and game-understanding as described in more depth in the following sections of
this chapter (Ackerman, 1998; Blomqvist et al., 2000; Gillet et al., 2009; 1993; Gagné 2008).

Validity considerations
The results of our validity studies correspond with the findings of other studies focusing on
the predictive value of underlying natural abilities for their sport of interest (Elliott, Ackland,
Blanksby, & Bloomfield, 1990; Panjan, Sarabon, & Filipčič, 2010; Pion et al., 2015; Vandorpe
et al., 2013). Elliott et al. (1990) and Panjan et al. (2010) both used observational designs
to predict tennis performance from anthropometric, physiological and perceptuo-motor in-
dicators. Comparable to our results, perceptuo-motor test items were considered the best
predictors for performance. However, the predictive value in these studies was difficult to
determine. Elliott et al. (1990) included only group comparisons regarding playing level at
different age groups (11, 13 and 15 years). No prediction models were presented for future
performance. Moreover, the accuracies of Panjan et al.’s models (2010) for the competition
performance at the age category 12-16 and after 16, based on both the assessment under
the age of 12 and 12-16 years, respectively, were poor with high errors.

Vandorpe et al. (2013) included young gymnasts (7-8 years), in which the potential to be-
come an elite gymnast was also considered to depend on perceptuo-motor skills. This
study showed that non-sport specific perceptuo-motor tests were significant predictors for
performance results in young elite gymnasts, explaining more than 40% of the competition
outcome two years later. In this study the ‘Körperkoordinations Test für Kinder’ was used
to measure the perceptuo-motor skills. The test items of this test battery appeal to a great extent on a child's ability to maintain balance in dynamic situations, which is in line with the specific demands of gymnastics. Moreover, the study of Pion et al. (2015) revealed that non-sport specific tests assessing perceptuo-motor skills discriminated between elite and sub elite adolescent volleyball players (p<0.036). The authors conclude that volleyball as a skill-based sport requires a well-developed perceptuo-motor skills level (Pion et al., 2015).

Consequently, it is suggested that perceptuo-motor skills indeed play an important role in the development of young player’s performance level in sports consisting of complex perceptuo-motor tasks. Testing underlying natural abilities of the perceptuo-motor domain fitting a particular sport seems appropriate. Yet, although we know that these assessments are some indicator for future performance, we are still unaware of the exact nature of these natural abilities or gifts. Do these assessment really assess natural abilities by using untrained perceptuo-motor tasks (Gagné, 2004)? Or could it be the ability to learn new and more complex skills (di Cagno et al., 2014), or some other underlying generic capacity? Nevertheless, it seems that the assessment of perceptuo-motor skills can be of added value in estimating a youth player’s potential for a certain sport.

High potential in table tennis

Gagné’s Differentiated Model for Giftedness and Talent

Gagné’s Differentiated Model for Giftedness and Talent 2.0 (Chapter 3: Figure 1) was introduced in Chapter 3 of this thesis. Gagné’s model presents the talent development process as the transformation of outstanding natural abilities, i.e. gifts, into outstanding systematically developed skills which define expertise, i.e. talent, in a particular field (Gagné, 2004). It is important to emphasize that this model differentiates between untrained and spontaneously expressed natural abilities (gifts) and the outstanding mastery of systematically developed skills (talent). Consequently, the definition of talent used in this model does not refer to someone with an exceptional natural aptitude, but is only used for experts that belong to the top 10 percent of their peers who have been active in that certain field. Moreover, the model includes intrapersonal and environmental catalysts, which define the factors within a player / person and the environment, respectively, that facilitate or hinder the developmental process, and chance. Gagné’s model for talent development provides a fundament to build up a more specific concept of high potential in table tennis.

Adaption of Gagné’s model to talent development in table tennis

The findings of the studies in this thesis are useful to fill Gagné’s model for the talent development process in table tennis. Consequently, an adaptation to the model is made based on this thesis’ results in which the content of the ‘boxes’ that present the model’s components (natural abilities (gifts), competencies (talents), intrapersonal and environmental catalysts, chance, development process) contain those elements considered important for table tennis (Figure 1). The different components are described in more detail in the follo-
wing paragraphs. Before reading the model’s details, it is important to explain the use of the concept ‘personal talent determinants’ in this thesis. The natural abilities (gifts) and the intrapersonal catalysts in Gagné’s model together are considered as the personal talent determinants, which are considered to reflect a youth player’s potential to reach the world’s highest level.

**Talent in table tennis**

The description of the component ‘competencies or talent’ for elite table tennis is based on chapter 9’s qualitative study and additional findings in literature. Elite players need outstanding ball, technical and tactical skills (Faber, Oosterveld, & Nijhuis-Van der Sanden, 2014; German Table Tennis Association, 2008; Horsch, 1990; Munivrana, Petrinović, & Kondrič, 2015a; Munivrana, Furjan-Mandić, & Kondrič, 2015b; Rodrigues, Vickers, & Williams, 2002). Any imperfection in these skills will weaken the player and his/her potential to reach and/or maintain at the elite level. Still, a distinctive skill that truly makes a player unique (i.e., the ‘x-factor’) might compensate for imperfections even at the highest level. Besides these skills, players must have excellent concentration, strategy and anticipation skills to be able to make quick adaptation to the continuously changing conditions (e.g., ball flight and ball rotation and opponent’s tactics) during the game (Ak & Koçak, 2010; Akpinar, Devilmez, & Kirazci, 2012; Bootsma, Fernandez, Morice, & Montagne, 2010; Sève, Saury, Theureau, & Durand, 2002). Moreover, self-confidence and well-developed mental skills will help the player to actually ‘live in the moment’ and deal with the emotional stress during and between matches (Chu, Chen, Chen, Huang, & Hung, 2012; Liu, Zhou, Ji, & Watson, 2012; Lopez & Santelices, 2012; Raab, Masters, & Maxwell, 2005). Finally, as table tennis has developed into fast-paced, explosive sport, the dependence on physical abilities is considerable (Lees, 2003). Players depend on their anaerobic system during the high-intensity bouts and use their aerobic capacity to recover between the rallies (Kondrič, Zagatto, Sekulić, 2013).

This summary of competencies of elite table tennis can help to find the specific underlying personal talent determinants that can be used for talent identification and also to improve the monitoring of the talent development process. Nevertheless, this is complicated by multiple factors. First, it is difficult to make a direct connection between the competencies (talent) and related natural abilities and find ways to assess these in youth players at a certain developmental stage. Second, the age of world level elite players vary from 18 up to 40 years and it is unknown at which age a player should reach a certain level to ensure success at the highest level. Third, as table tennis evolves over time the competencies to reach and maintain at the elite level are subject to change. Talent identification and development will only have success when trainers and coached have an adequate vision about the sport’s evolution. This evolution includes changes in techniques and tactics (playing styles), physical demands, materials, game rules and regulations and policies.

**Natural abilities**

The natural abilities or gifts as described by Gagné (2004) connect to the categories ‘fit to table tennis’ and ‘learning fast’ proposed in chapter 9. According to the profile of elite play-
ers and the interviews with the elite players and their trainers, extremely gifted youth table tennis players should stand out from the crowd by showing an exceptional handling of the ball under varying conditions, excellent gross motor functions (e.g. speed and agility) and fast learning. Especially the latter one is suggested to reflect the player’s level of giftedness or potential (Ackerman, 1998; Ericsson, Krampe, Tesch-Römer, 1993; Gagné 2008). Youth players with fitting natural abilities for table tennis are able to make essential improvements in their play. Probably these players implicitly or explicitly know what they are able to do, what they need and can improve, which information they need to select and how they benefit from this in their matches. The results from chapter 4 and 8 indeed support the hypothesis that youth players with better perceptuo-motor skills tend to outperform players with lower results in future. Consequently, these skills seem to be correctly suggested as natural abilities for elite performance in table tennis.

Besides the perceptuo-motor skills, game-intelligence (‘read the game’), creativity, problem-solving, anticipation and the ability to train were brought on the table by the elite players and their trainers as essential natural abilities for elite table tennis. From the systematic review in chapter 3 it has been shown that there is limited evidence that the more complex

![Figure 1. Adaptation of Gagné's Model for Giftedness and Talent for excellence in table tennis.](image-url)
mental tasks (i.e. game understanding and anticipatory skills tests) can be used for talent developmental purposes to distinguish elite from non-elite players and to give direction to training in table tennis, badminton and tennis (Bańkosz, 2012; Blomqvist, Luhtanen, Laakso, & Keskinen, 2000; Mantis, Zachopoulou, & Mavridis, 1998). Also one of our unpublished studies showed that elite and sub elite table tennis players scored above average when compared to the norm population (including age-peers) in tasks which appeal to the executive functions. Moreover, the complex inhibition tasks seem even be able to discriminate between the elite and sub elite players (De Vries, Verwoert, Van Otten, & Faber, 2013).

**Intrapersonal catalysts**

The systematic review (chapter 3) also revealed that physical appearance can have benefits at a certain period in youth racquet sport players. Although light-weighted players are suggested to have advantages compared to players with a higher percentage of fatty tissue (Nikolić, Furjan-Mandić, & Kondrič, 2014), it is still unknown at what time a player needs to fit a certain physical profile to become a world class player. Differences in growth, development and maturation interfere with such outcomes and impede an adequate interpretation (Malina, Cummings, Morano, Barron, & Miller, 2005; Coelho E Silva et al., 2010). Probably controlling for inter-individual differences using maturity indicators, e.g. body proportionality (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002), will provide more valid results. Yet, taking the world ranking into account, players with different physical profiles can be distinguished within the world’s top 50. To all probability it is more important that players use and optimize the benefits of their physical profile than fitting one specific physical profile.

The players and trainers added ‘not getting injured’ as an important facilitator to the model (chapter 9). The player must be able to withstand the enormous amount of training and competition over a long period in time. Although details of injuries in racquet sports, or specifically table tennis, are not well documented, the injury risk in racquet sports is generally considered as low compared to other sports (Lees, 2003). Nevertheless, both acute and overuse injuries of the musculoskeletal system are reported as a consequence of performing racquet sports. Players and trainers should be aware of this. Additionally, one could discuss the interrelationship between the physical and mental factors concerning this issue (Lavallée & Flint, 1996; Martinent & Decret, 2015).

The other intrapersonal catalysts, i.e. the mental traits and goal-management catalysts, are hypothesized to be important for an effective and efficient developmental process in chapter 3. Motivation and self-esteem and associated mental aspects have been shown to be associated to success in tennis and are considered important for realising optimal performance (Gillet, Berjot, & Gobancé, 2009; Lane, Jones, & Stevens, 2002). It seems likely that the (predictive) value of these personal talent determinants can be generalized to table tennis.

**Environmental catalysts and chance**

The environmental catalysts and chance were not studied in detail in this thesis as it focused on the personal talent determinant (natural abilities and intrapersonal catalysts) of
youth table tennis players. Yet, as concluded in chapter 9, the concept of high potential for elite table tennis cannot be regarded without information about the player’s context and the specifications of the task over time (Gagné, 2004; Newell, 1986). Parental influences on the choice for table tennis as a sport, the early exposure to table tennis, the challenging context during deliberate play, the (financial) support and encouragement during training and competition and guarding of the player’s personality development are highly important in facilitating the developmental process (McCullagh, Matzkanin, Shaw, & Maldonado, 1993). Moreover, the right trainer and coach during the different phases of development is mentioned by the elite players and trainers to be essential for an optimal development. The ‘system’ of a nation’s table tennis association also influences the development on macro level. The association’s policies regarding regulations and criteria for competition and selections effect the player’s development by emphasizing certain personal talent determinants during development. This leads to better opportunities for training and competition for those players fulfilling the chosen profile. Not being selected often means that players miss opportunities for training and competition in which they learn from the better / best players. These opportunities, however, are considered to be crucial for further development to reach the elite level. Finally, also the evolution of the game and changes in game regulations effect the talent developmental process by changing the task over time (Cobley, Schorer & Baker, 2012). Especially at the highest level small changes can have a large impact on player and he/she need to adapt to these changes adequately and in time for reaching or maintaining competing at the elite level.

Considerations

As suggested earlier, the natural abilities and intrapersonal catalysts are considered to express a player’s potential to reach the world-class level in table tennis based on personal talent determinants. Excellent natural abilities and highly facilitating intrapersonal catalysts for the development of table tennis expertise will increase the chance to become an elite table tennis player. If specific personal talent determinants can be determined for future elite table tennis and can be assessed within youth table tennis player, then it is possible to get a better grip on what high potential for elite table tennis implies. Nevertheless, the influence of environmental factors and chance on the talent developmental process must not be underestimated. Moreover, although the arrows in Gagné’s model describe the developmental process, all parts of the model are interrelated and change over time which complicates interpretation about causality and mediation (Gagné, 2004). Reaching the elite level in table tennis can, for that reason, not be guaranteed even when a youth player presents a high potential at a young age (6-12 years), it will only enlarge his / her chances to a certain degree.

As one can notice not all competencies of elite table tennis can be directly derived from the natural abilities or intrapersonal catalysts in the model (Figure 2). Two explanations for this are recognised. First, although some skills are described as highly important for elite performance, these skills were not proposed to be important talent determinants at a young age (≤ 12 years), since these are often considered to be sufficient trainable during
the development process. An example of this is the physical fitness level. During the developmental process, all players aiming for the elite level start a physical training for better performances. Their explosive power, anaerobic and aerobic endurance need to be optimal for outstanding performances. Although some players might drop out because they cannot keep up with the physical demands during the talent development process, it was not proposed as a fundamental stone by the elite players and trainer at an early age yet. The second explanation is that some characteristics are suggested to develop later in time or are only noticeable at a later stage and cannot be assessed at an early age (≤ 12 years). In this case, the elite players and trainers especially appointed the aspects concerning volition, e.g. self-regulation and full dedication and commitment. Longitudinal monitoring during the developmental process of natural abilities derived from all competencies will gain a better understanding at what point in time a player needs to fit a certain profile to be able to reach the elite level in table tennis.

**Directions for future research**

The results of the studies in this thesis reveal new insights and gain hypotheses for further research. It is important to acknowledge that, at this point in time, scientific evidence focusing on the assessment of potential for talent development purposes in table tennis is scarce. The systematic review included as chapter 3 revealed only five studies focusing on table tennis, including the one of chapter 5 of this thesis. Although many associations, dealing with low budgets and a relative low number of players, try to find ‘diamonds in the rough’, there is obvious a lacuna in this field which highlights the importance of this thesis.

Concerning the value of the perceptuo-motor skills assessment for practical use by trainers and coaches, it is important that more data will be gathered using an international sample to gain norm values. Moreover, longitudinal studies including elite players will help to find cut-off scores for the prediction of high performance in youth table tennis players. Perhaps the prediction of high performance could also be enhanced by using a performance curve based on repeated measurements over time.

Further future research might focus on a multidisciplinary approach for assessing potential in youth table tennis players (Elferink-Gemser et al., 2011; Philips, Davids, Renshaw, & Portus, 2010). The studies in this thesis mainly focused on the perceptuo-motor domain with only one assessment at an early age (≤ 10 years) in Dutch table tennis players. Prediction models are hypothesised to improve from the inclusion of both physical and mental assessments, which are monitored more frequently during development. Prospective longitudinal studies carried out over a longer period of time (5-10 years) including an international sample should give a better insight in the capability of models to predict future performance. These studies should also include methods to discover the influence of differences in growth and maturation during development (Coelho E Silva et al., 2010; Mirwald et al. 2002).
Besides this, studies exploring other possible personal talent determinants are suggested to gain a better understanding of high potential for table tennis. For example, recent studies focusing on the executive functions suggest the importance of these natural abilities for success in sports (Huigen et al., 2015; Verburgh, Scherder, van Lange, & Oosterlaan, 2014; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). As table tennis is one of the fastest sports in term of game speed (Abernethy, 1991), these functions might play an important role. Another example is the influence of the stress level on performance (Sperlich et al., 2012). Although earlier research demonstrated that the cardiorespiratory and metabolic demands are low during training and match play, the measurement of the stress level (i.e. cortisol level) could reveal differences between high and low performers indicating a key-element for future success (Sperlich, Koehler, Holmberg, Zinner, & Mester, 2011).

Finally, game-analysis in youth elite table tennis players might give a better knowledge of the demands for matches throughout the development. At this moment mainly adult game analysis results are available (Munivrana et al., 2015a; Munivrana et al., 2015b; Pradas, Floria, Carrasco, Beamonte, & González, 2010). Analyses of matches in elite youth players at the different stages during development might help to find indicators for high performance at a certain age and point out new evolutions in table tennis sports. Also, qualitative studies can be conducted to draw up new hypotheses and unravel the mystery of high potential and high performance even further.

Concluding remarks

This thesis emerged in response to the request for help in finding those table tennis youth players with the potential to become a world-class elite player. In daily practice, scouts, trainers and table tennis associations have difficulties to estimate a young player’s potential adequately due to the influences of individual differences in growth, maturation, development and learning curves, training experiences, competition participation and environmental factors. The results of our studies create a scientific basis to support those involved in the selection of youth players for talent developmental programmes to make better judgements.

Based on the studies described in this thesis it can be concluded that:

- In the field of talent development in racquet sport and especially table tennis, there is a lack of studies including a longitudinal design, which hinders the evaluation of the predictive value of assessment of youth players (chapter 3).
- Instruments focusing on intellectual and perceptual abilities or coordinative skills are hypothesized to measure essential natural abilities for racquet sport as these instruments can discriminate elite from non-elite racquet sport players and/or the test outcomes are related to current performance (chapter 3).
- Perceptuo-motor skills including ball skills and gross motor functions are considered to be essential underlying skills, i.e. natural abilities, for elite table tennis (chapter 4-8).
• The Dutch perceptuo-motor skills assessment is a reproducible tool, which significantly contributes to the prediction of table tennis performance of youth table tennis players in Netherlands (chapter 4-8).
• Talent development in table tennis should be considered as a multidimensional process in which the potential of a youth player can only be described in relation with the task and the player’s context (chapter 9).

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CHAPTER 10


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Summary
This thesis is concerned with the search for high potentials in table tennis by exploring crucial personal talent indicators for success at an adult age and methods how to assess these in youth table tennis players. Chapter 1 introduces the rationale for this thesis by explaining the struggles in practice regarding the search for high potential in youth table tennis players. In chapter 2, the thesis’ research proposal is introduced. This chapter emphasizes the motivation, justification and design for the studies in the following chapters. Both top-down and bottom-up approaches are described to gain more insight into the determinants playing a key-role in the development of youth table tennis players to elite level.

Chapter 3 presents a systematic review including a state-of-the-science overview of instruments measuring personal talent determinants of young players in racquet sports. Thirty studies, mainly conducted in the field of tennis, covered more than 100 instruments used for talent development. Gagné’s Differentiated Model of Giftedness and Talent 2.0 was used to classify the instruments. Most instruments focused on physical characteristics. Only minor studies were found paying attention to instruments assessing mental qualities. Furthermore, the instruments were evaluated with regard to their ability to discriminate between elite and non-elite players, to predict future performance and to give direction to talent development. This validity evaluation regarding talent development showed that instruments focusing on intellectual and perceptual abilities or coordinative skills discriminate elite from non-elite players and/or the test outcomes are related to current performance, but their predictive validity is not confirmed. Only moderate evidence was found that the assessments of mental and goal-management skills predict future performance. Data on instruments measuring physical characteristics prohibit a conclusion due to conflicting findings. Especially the lack of longitudinal studies precluded the verification of the instrument’s capacity to forecast future performance.

Chapter 4 tries to fill this gap by examining the capability of the motor test items ‘sprint’, ‘agility’, ‘speed while dribbling’ and ‘throwing a ball’ to predict table tennis performance. These test items were included in the perceptuo-motor skills assessment of the Netherlands Table Tennis Association from 1998 till 2012 during the annual national talent days. Youth players (n=1191) were assessed using these items at an age between 7-10. This provides the opportunity to evaluate the predictive value of the items for the players’ table tennis performances during the final season U13, U15 and U18 (1999-2013). The univariable and multivariable logistic and linear regression analyses revealed that ‘sprint’, ‘speed while dribbling’ and ‘throwing a ball’ made a significant contribution to the prediction models. Nevertheless, as the accuracies of the models were low, the advice was to include other determinants of the perceptuo-motor and other domains and measure these longitudinally to enhance the predictive value of a model for table tennis performance.

In order to enhance the perceptuo-motor skills assessment an eye-hand coordination test was developed. This test item ought to measure eye-hand coordination and ball control under time pressure considered to be underlying perceptuo-motor skills essential for table tennis. Together with the trainers of the Netherlands Table Tennis Association, a test was proposed
in which children needed to throw a ball against a table tennis table in a vertical position with one hand and to catch the ball correctly with the other hand as frequently as possible in 30 seconds. Chapter 5 pays attention to the evaluation of four different test versions varying the distance to the table (1 or 2 meters) and using a tennis or table tennis ball. The ability to discriminate players from national, regional and local training levels and reproducibility were evaluated. Overall the test protocol involving the 1 meter distance and the table tennis ball was evaluated as the most adequate regarding its psychometric characteristics.

Chapter 6 presents the first evaluation of the reproducibility and validity of the Dutch perceptuo-motor skills assessment. The assessment at that time consisted of eight test items covering two latent variables ‘gross motor function’ and ‘ball control’ according to the principal component analysis. Six test items showed acceptable reproducibility (ICC >0.7) with coefficients of variation between 3-8%. The associations between the total score of the perceptuo-motor skills assessment’s results and national ranking (concurrent validity) was moderate as hypothesized; boys r=−0.53 (p<0.001) and girls r=−0.45 (p<0.015). It was recommended that the test items ‘aiming at target’ and ‘ball skills’ needed revision due to irreproducible test outcomes.

Accordingly, chapter 7 pays attention to the revision of these test items. New test protocols were developed in cooperation with the expert trainers of the Netherlands Table Tennis Association while taking the recommendations for revision into account: more attempts, fewer variations in subtasks and a more extensive scale for the target. The reproducibility of the revised test items was evaluated by means of a test-retest design, and the validity of the revised test items by (1) testing the discriminative capacity using a known-group design and (2) the correlation between the test outcomes and competition results. The revised protocols showed acceptable reproducibility (ICC>0.7). The validity was also considered sufficient as the test outcomes discriminated between the players from the national and local training centres and a moderate association was found in the competition results. Consequently, the revised test protocols were incorporated in the Dutch perceptuo-motor skills assessment.

As talent indicators are especially of value if they can predict table tennis performance over time, evaluating the predictive validity in a prospective study is important. In order to do so, the observational prospective study described in chapter 8 was conducted. Youth players participating during a regional talent day were assessed and the subsequent competition results were recorded every six months over a period of 2.5 years. The logistic regression analysis showed that test scores did not predict future competition participation in this sample (p>0.05). Yet, the longitudinal Generalized Estimating Equations analysis based on the subsample of competition players, including the test items ‘aiming at target’, ‘throwing a ball’, and ‘eye-hand coordination’ in the best fitting model, revealed that the outcomes of the perceptuo-motor skills assessment were significant predictors for future competition results. Future studies are needed to clarify the predictive value in a larger sample of youth competition players over a longer period in time.
Since talent development is considered a multidimensional and complex process, it was evident that not only personal talent determinants (of the perceptuo-motor domain) should be evaluated. However, as the identification and selection of high potential youth players is a challenge and measuring the potential for elite table tennis is still a wasteland, new hypotheses about important key-factors need to be developed. Consequently, a qualitative approach was used to explore the nature of high potential for table tennis and to provide a better understanding of the success factors. In chapter 9, the explorative qualitative study regarding the perspectives of elite players and their trainers from the formative years is presented. Seven interrelated themes were derived from the semi-structured in-depth interviews with the players and trainers: early exposure, deliberate play, fit to table tennis, learn fast, taking the next step, constant competition and reaching the top of the world. Each theme demonstrated that 'high potential' for elite table tennis can only be described with reference to the four elements: the player, the task table tennis, the environment and development over time. The perspectives of the elite players and trainers presented in this chapter give direction to further studies focusing on the concept of 'high potential' for elite table tennis and to ways of assessing or monitoring this in young table tennis players.

Chapter 10 discusses the main findings from the preceding chapters and provides a proposal regarding the implication for practice. The following conclusion can be drawn from this thesis:

1. In the field of talent development in racquet sport and especially table tennis, there is a lack of studies including a longitudinal design, which hinders the evaluation of the predictive value of assessment of youth players.

2. Instruments focusing on intellectual and perceptual abilities or coordinative skills are hypothesized to measure essential natural abilities for racquet sport as these instruments can discriminate elite from non-elite racquet sport players and/or the test outcomes are related to current performance.

3. Perceptuo-motor skills including ball skills and gross motor functions are considered to be essential natural abilities for elite table tennis.

4. The Dutch perceptuo-motor skills assessment is a reproducible tool, which significantly contributes to the prediction of table tennis performance of youth table tennis players in Netherlands.

5. Talent development in table tennis should be considered as a multidimensional process in which the potential of a youth player can only be described in relation with the task and the player's context.
Samenvatting
Dit proefschrift gaat over de zoektocht naar ‘high potentials’ voor de tafeltennissport door het verkennen van cruciale talentindicatoren binnen tafeltennissers voor succes op volwassen leeftijd en de methodes om deze indicatoren in jeugdspelers te meten. **Hoofdstuk 1** introduceert de rationale voor de probleem- en vraagstelling van dit proefschrift. De uitdagingen uit de praktijk van de tafeltennisbond, de trainer en coach worden beschreven als het uitgangspunt voor de zoektocht naar een wetenschappelijk fundament. In **hoofdstuk 2** wordt het onderzoeksvoorstel beschreven welke als fundament dient voor dit proefschrift. Dit hoofdstuk benadrukt de motivatie, de rationele en het onderzoeksdesign voor de studies van de hoofdstukken 3 t/m 9. Zowel ‘top-down’ als ‘bottom-up’ studiedesigns worden besproken. Deze verschillende benaderingen dragen bij aan het verkrijgen van meer inzicht in essentiële determinanten voor de ontwikkeling van een jeugdtafeltennisser tot een volwassen wereldtopper.

**Hoofdstuk 3** beschrijft een systematische literatuurstudie. In deze literatuurstudie wordt een ‘state-of-the-science’ overzicht gepresenteerd van instrumenten voor het meten van persoonlijke talentdeterminanten in jeugdspelers welke worden gebruikt binnen racketsporten. Meer dan 100 instrumenten voor talentontwikkeling werden gedestilleerd uit 30 geïncludeerde wetenschappelijke studies. De studies waren voornamelijk uitgevoerd binnen tennis. Alle gevonden meetinstrumenten werden geclassificeerd met behulp van het ‘Differentiated Model of Giftedness and Talent 2.0’ van Gagné. De meeste van de gevonden instrumenten richtten zich op het meten van fysieke kenmerken. Slechts een klein deel van de studies besteedde aandacht aan het beoordelen van mentale kwaliteiten. Naast het classificeren werd ook de validiteit van de instrumenten voor talentontwikkeling geëvalueerd. Hiervoor werden de instrumenten beoordeeld op hun vermogen om (1) onderscheid te maken tussen elitespelers en niet-elitespelers, (2) toekomstige prestaties te voorspellen en (3) richting te geven voor het talentontwikkelingsprogramma. Uit deze evaluatie bleek dat de instrumenten voor het meten van intellectuele en perceptuele capaciteiten en de instrumenten die coördinatievaardigheden meten in staat zijn om elite- en niet-elitespelers van elkaar te onderscheiden en/of in staat zijn een associatie aan te tonen met de actuele prestatie. Desalniettemin werd de voorspellende waarde van deze instrumenten niet bevestigd. De bewijskracht voor de voorspellende waarde van de uitkomsten van de instrumenten gericht op mentale en ‘goal-management’ vaardigheden was gering. Ten aanzien van de fysieke testen kon geen eenduidige conclusie worden getrokken aangezien er sprake was van tegenstrijdige bevindingen. Vooral het gebrek aan longitudinale studies zorgt ervoor dat er de voorspellende waarde van de meeste instrumenten niet kon worden geverifieerd.

Met de studie in **hoofdstuk 4** is getracht dit hiat op te vullen. Deze studie richtte zich op de evaluatie van de voorspellende waarde van de perceptuomotorische testitems ‘sprint’, ‘behendigheid’, ‘snelheid met bal’ en ‘balletje gooien’. De testitems beogen essentiële onderliggende vaardigheden voor tafeltennis te toetsen bij jonge spelers (≤10 jaar). Deze testitems waren onderdeel van de perceptuomotorische testbatterij welke werd gebruikt tijdens de jaarlijkse landelijke talentendag van de Nederlandse Tafeltennis Bond van 1998-2012. Jeugdspelers (n=1191) werden getoetst op een leeftijd tussen de 7 en 10 jaar met behulp
van deze testitems. Daarna werden de tafeltennisprestaties van deze spelers longitudinaal gemonitord, waarbij de prestaties van het laatste competitie seizoen werden bepaald in de leeftijdscategorie pupil (U13), kadet (U15) en junior (U18). Uit de univariabele en multivariabele logistische en lineaire regressie analyses bleek dat de testitems „sprint”, „snelheid met bal” en „balletje gooien” een significante bijdrage leverden aan de predictiemodellen. Uit de studie bleek dat de accurateheid van deze modellen laag was. Hieruit concludeerden we dat ook andere determinanten voor prestatie van het perceptuomotorische domein of andere domeinen moeten worden toegevoegd en longitudinaal getoetst voor de verbetering van de voorspellende waarde van de modellen voor tafeltennisprestatie.

Daaropvolgend werd een oog-handcoordinatietest ontwikkeld om de perceptuomotorische testbatterij te verbeteren. Dit testitem beoogt de oog-handcoördinatie en balcontrole onder tijdsdruk te meten als essentiële onderliggende vaardigheid voor tafeltennis. Samen met de trainers van de Nederlandse Tafeltennisbond werd een testitem ontwikkeld waarbij jeugdspelers zo vaak mogelijk in 30 seconden een bal tegen een verticaal gepositioneerde tafelhelft gooien met de ene hand en daarna correct vangen met de andere hand. In hoofdstuk 5 wordt een studie beschreven welke vier testversies evalueert waarbij de afstand tot de verticale tafelhelft (1 of 2 meter) en de bal (tennis of tafeltennisbal) werd gevarieerd. Het doel was om vast te stellen welke van de testversies het beste discrimineerde tussen jeugdspelers van de nationale, regionale en lokale trainingselecties. Ook werd de reproduceerbaarheid getoetst. De testversie met een afstand van 1 meter tot de tafelhelft en de tafeltennisbal bleek het meest geschikt.

Hoofdstuk 6 presenteert de eerste evaluatie van de reproduceerbaarheid en validiteit van de Nederlandse perceptuomotorische testbatterij. De testbatterij bestond op dat moment uit acht testitems. Uit de ‘principal component analysis’ kwam naar voren dat ‘gross motor function’ en ‘ball control’ twee onderliggende constructen waren binnen de testbatterij. Zes testitems leverden reproduceerbare uitkomsten (ICC>0.7; variatiecoëfficiënt 3-8%). De associatie tussen de totale score van de testbatterij en de nationale ranglijstpositie (concurrente validiteit) was zoals verwacht matig: voor jongens r=-0.53 (p<0.001) en voor meisjes r=-0.45 (p=0.015). Vanwege de onvoldoende reproduceerbare uitkomsten werd geadviseerd de testitems ‘mikken op doel’ en ‘balvaardigheid’ te reviseren.

Derhalve is in hoofdstuk 7 aandacht besteed aan de revisie van deze testitems. Nieuwe testprotocollen werden ontwikkeld in samenwerking met experttrainers van de Nederlands Tafeltennis Bond, waarbij rekening is gehouden met de volgende aanbevelingen voor revisie: meer pogingen, minder taakvariaties en een uitgebreidere schaal voor de gebruikte doelen. De reproduceerbaarheid werd onderzocht op basis van een ‘test-hertest’ design. Daarnaast is de validiteit geëvalueerd door (1) het discriminerend vermogen te toetsen met behulp van een ‘known-group’ design en (2) de correlatie tussen de testitemuitkomsten en de competitieresultaten te bepalen. De scores op basis van de gereviseerde testprotocollen waren voldoende reproduceerbaar (ICC>0.7). Ook de validiteit werd als voldoende beschouwd aangezien de testscores van de nationale trainingsgroep significant verschil-
den van de lokale trainingsgroep en er zoals verwacht een matige associatie was met de competieteresultaten. Op basis van deze resultaten zijn de oude door de gereviseerde testitems vervangen.

Aangezien talentindicatoren vooral van waarde zijn als zij de tafeltennisprestatie over de tijd kunnen voorspellen, is het van belang de voorspellende waarde in een prospectieve studie te onderzoeken. Om deze reden werd de observationele prospectieve studie van hoofdstuk 8 uitgevoerd. De testbatterij werd afgenomen bij jeugdspelers van een regionale talentendag. Daarna werden gedurende 2,5 jaar elk half jaar de resultaten van deze jeugdspelers van daaropvolgende competitie seizoenen verzameld. Uit de logistische regressie-analyse blijkt dat de testresultaten niet voorspellend waren voor het wel of niet deelnemen aan de competitie gedurende de follow-up periode. Echter, de Generalized Estimating Equations analyse van de resultaten van de competitiepelende jeugd gaf aan dat de perceptuomotorische testbatterij weldegelijke een significante voorspeller is voor de competieteresultaten. De testitems 'mikken op doel', 'balletje gooien' en 'oog-hand coördinatie' werden opgenomen in het 'best fitting' model. Longitudinale studies met een langere follow-up en grotere steekproef moeten meer duidelijkheid bieden over de voorspellende waarde voor competitiepelers op langere termijn.

Talentontwikkeling wordt beschouwd als een multidimensionaal en complex proces. Het is duidelijk dat meer factoren een rol spelen dan persoonlijke talentdeterminanten (van het perceptuomotorische domein). Het identificeren en selecteren van 'high potentials' blijft een uitdaging, waarbij het meten van potentie nog een braakliggend terrein is. Om deze redenen is het van belang om nieuwe hypothesen te ontwikkelen over de cruciale sleutelfactoren voor talentontwikkeling binnen tafeltennis naar het allerhoogste niveau. Vandaar dat een kwalitatieve studie is uitgevoerd naar de aard van 'high potential' voor de tafeltennissport om een beter inzicht te verkrijgen in de succesindicatoren. In hoofdstuk 9 wordt deze exploratieve kwalitatieve studie gepresenteerd, waarbij 'high potential' is beschreven vanuit de perspectieven van elitespelers en de trainers uit hun jeugdperiode. Uit de semi-gestructureerde diepte-interviews met elitespelers en hun trainers werden zeven met elkaar samenhangende thema's gestedilleerd: 'early exposure', 'deliberate play', 'fit to table tennis', 'learn fast', 'taking the next step', 'constant competition' en 'reaching the top of the world'. Elk thema demonstreerde dat 'high potential' slechts kan worden beschreven met de verwijzing naar vier elementen: de speler, de taak, de omgeving en de ontwikkeling in de tijd. De gepresenteerde perspectieven van de spelers en trainers geven richting aan vervolgstudies welke zich focussen op het concept van 'high potential' voor tafeltennis op wereldniveau en methodes om dit te toetsen en te monitoren bij jeugdspelers.
Hoofdstuk 10 bespreekt de belangrijkste bevindingen van de voorgaande hoofdstukken en biedt een handreiking voor de implicaties in de praktijk. De volgende conclusies kunnen op basis van dit proefschrift worden getrokken:

1. Op het gebied van talentontwikkeling binnen de racketsporten, en zeker binnen tafeltennis, is er een gebrek aan longitudinale studies, wat de evaluatie van de predictieve waarde van de testresultaten van jeugdspelers belemmert.

2. Instrumenten, welke worden gebruikt voor het meten van intellectuele en perceptuele vaardigheden of coördinerende vaardigheden, worden verondersteld essentiële onderliggende vaardigheden voor racketsporten te kunnen meten bij jeugdspelers, aangezien de testresultaten van deze instrumenten elite van niet-elite racketsportjeugdspelers kunnen discrimineren en/of de resultaten een relatie hebben met de huidige prestaties.

3. Perceptuo-motorische vaardigheden, waaronder balvaardigheid en grove motorische vaardigheden worden beschouwd als essentiële onderliggende vaardigheden voor elite tafeltennis.

4. De Nederlandse testbatterij voor perceptuo-motorische vaardigheden geeft reproduceerbare testresultaten bij tafeltennisers t/m 10 jaar en draagt significant bij aan de voorspelling van tafeltennisprestaties van de jeugdtafeltennisers in Nederland.

5. Talentontwikkeling binnen tafeltennis moet worden beschouwd als een multidimensionaal proces, waarin het potentieel van een jeugdspeler alleen kan worden beschreven in relatie met de taak en context van de speler.
Dankwoord

Dit boek is bijna uit, maar dat kan niet zonder een dankjewel voor iedereen die op één of andere manier een steentje heeft bijgedrag. Gedurende deze reis heb ik mijn eigen talentenpad samen met mijn omgeving samen ontdekken en vormgeven. Vooral het door jullie geschonken vertrouwen is voor mij een belangrijke basis geweest om mezelf verder te ontwikkelen, grenzen te verleggen en te volharden om mijn doelen te bereiken. Zonder jullie had ik het niet gekund, daarom dankjewel!

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Per 2015 is Irene verkozen als ‘full member’ van de ‘Sports Science and Medical Committee’ van de International Table Tennis Federation. In de komende jaren hoopt zij het onderzoek naar talentontwikkeling binnen de sport voort te zetten, zowel in Nederland als internationaal.

Irene woont samen met Rogier Gerritsen en hun drie kinderen Quinten, Floortje en Roos in Twello.
DIAMONDS IN THE ROUGH
List of Publications

Articles

International


Faber IR, Oosterveld FGJ, van den Heuvel SCGH, Bustin PMJ, Elferink-Gemser MT, Nijhuis-Van der Sanden MWG (2015) High potential in table tennis from the perspectives of elite players and their youth trainers: an explorative qualitative study. Submitted for publication.


Other


Faber IR, Elferink-Gemser MT, Oosterveld FGJ, Nijhuis-Van der Sanden MWG (2016) Worin bestaat de (Mehr-)Wert motorischer Testverfahren im Rahmen der Sichtung und Förderung von Talenten? Trainerbrief 1: 4-10.


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Faber IR, Oosterveld FGJ, Nijhuis-Van der Sanden MWG. Revision of two test items of the Dutch talent identification assessment measuring ball control in young athletes; a validity and reproducibility study. 13th ITTF Sport Science Congress; 2013 May 11-12; Paris, France.

Faber IR, Oosterveld FGJ, Nijhuis-van der Sanden MWG. Evaluation of an eye-hand coordination test for talent identification in table tennis; a validity and reproducibility study. 17th Annual Congress of the European College of Sport Science; 2012 Jul 4-7; Bruges, Belgium.

Faber IR, Nijhuis-Van der Sanden MWG, Oosterveld FGJ. Evaluation of an eye-hand coordination test to discriminate between talents and non-talents. 17th Annual Congress of the European College of Sport Science; 2012 Jul 4-7; Bruges, Belgium.

Faber IR, Oosterveld FGJ, Nijhuis - van der Sanden MWG. The Dutch National Talent Day: a first step to an evidence-based talent identification program. 12th ITTF Sport Science Congress; 2011 May 5-7; Rotterdam, The Netherlands.

Faber IR, Oosterveld FGJ, Nijhuis - van der Sanden MWG. Concurrent validity of test items from a talent identification test battery. 12th ITTF Sport Science Congress; 2011 May 5-7; Rotterdam, The Netherlands.
Co-authored


Brink EM van den, Faber IR. ‘Return to play’ criteria na een enkel inversietrauma. VSG Sportmedisch Wetenschappelijk Jaarcongres 2014; 2014 Nov 27-28; Ermelo, The Netherlands.

Van der Voet M, Faber IR. ‘Heeft het type spikes invloed op de loophouding?’ – Onderzoek naar de invloed van sprint en middellange afstand spikes op de loophouding van baanatleten. VSG Sportmedisch Wetenschappelijk Jaarcongres 2013; 2013 Nov 29; Ermelo, The Netherlands.


Ekman S, Faber IR, Oosterveld F.G.J, Nijhuis - van der Sanden MWG. Reliability study of a motor test battery for talent identifier. 12th ITTF Sport Science Congress; 2011 May 5-7; Rotterdam, The Netherlands.
RIHS PhD Portfolio

<table>
<thead>
<tr>
<th>Name PhD student:</th>
<th>PhD period:</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.R. Faber</td>
<td>01-02-2012 – 31-1-2016</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Department:</th>
<th>Promotor(s):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Institute for Quality of Healthcare</td>
<td>Prof. M.W.G. Nijhuis-Van der Sanden</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Graduate School:</th>
<th>Co-promotor(s):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radboud Institute for Health Sciences</td>
<td>Dr. F.G.J. Oosterveld</td>
</tr>
<tr>
<td></td>
<td>Dr. M.T. Elferink-Gemser</td>
</tr>
</tbody>
</table>

### TRAINING ACTIVITIES

#### a) Courses & Workshops

<table>
<thead>
<tr>
<th>Course/Workshop</th>
<th>Year(s)</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>Cambridge Proficiency English (Saxion)</td>
<td>2014</td>
<td>2</td>
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<tr>
<td>Workshop Atlas.ti te Nijmegen (UMC Radboud)</td>
<td></td>
<td>0.2</td>
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<tr>
<td>CARE cursus kwalitatief onderzoek (UMC Radboud)</td>
<td></td>
<td>0.8</td>
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<tr>
<td>Workshop systematische reviews ( Hogeschool Zuyd)</td>
<td></td>
<td>0.4</td>
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<tr>
<td>Mixed Models – multilevel en longitudinale data-analyse (TriData)</td>
<td>2013</td>
<td>20</td>
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<tr>
<td>BROK cursus (UMC Radboud)</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>NCEBP cursus (UMC Radboud)</td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>K78 Kwalitatief onderzoek in de praktijk van de gezondheidszorg (EpidM)</td>
<td>2012</td>
<td>1.2</td>
</tr>
</tbody>
</table>

#### b) Seminars & lectures

**Lectures**

<table>
<thead>
<tr>
<th>Event</th>
<th>Year(s)</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Team Table Tennis Championships, workshop 'Talent Identification 'Finding diamonds in the rough', 2016 Mar, Kuala Lumpur, Maleisi.</td>
<td>2016</td>
<td>0.5</td>
</tr>
<tr>
<td>ABIN/AMRO Foundation, Ambassadeuravond, lezing 'talenterkenning in de (tafeltennis) sport', 2015 Oct, Amsterdam, The Netherlands.</td>
<td>2015</td>
<td>0.25</td>
</tr>
<tr>
<td>Vereniging van Tafelennistrainers (VVT), Landelijke Technische Bijeenkomst, lezing/workshop 'Talentherkenning &amp; - ontwikkeling', 2015 Jun, Ede, The Netherlands.</td>
<td>2015</td>
<td>0.5</td>
</tr>
<tr>
<td>Hockey Club Twente, 9e Sportavond, lezing 'talent is goed, ambitie is beter', 2013 Nov, Hengelo, The Netherlands.</td>
<td>2013</td>
<td>0.25</td>
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**Panel discussion**

<table>
<thead>
<tr>
<th>Event</th>
<th>Year(s)</th>
<th>ECTS</th>
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<tbody>
<tr>
<td>Vereniging van Tafelennistrainers (VVT), Landelijke Technische Bijeenkomst 'Talentherkenning &amp; - ontwikkeling',2015 Jun, Ede, The Netherlands.</td>
<td>2015</td>
<td>0.25</td>
</tr>
<tr>
<td>Hockey Club Twente, 9e Sportavond 2013, 'Talentontwikkeling', 2013 Nov, Hengelo, The Netherlands.</td>
<td>2013</td>
<td>0.25</td>
</tr>
<tr>
<td>Hengelose Korfbal Club, 100-jarig jubileum, 'Talentherkenning en -ontwikkeling', 2013 May, Hengelo, The Netherlands.</td>
<td>2013</td>
<td>0.25</td>
</tr>
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</table>
### c) Symposia & congresses

#### Key note lectures

<table>
<thead>
<tr>
<th>Title</th>
<th>Year</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>High potential in table tennis from the perspectives of elite players and their youth trainers: A multiple case-study. 14th ISTFSports Science Congress; 2015 Apr 23-25, Suzhou, China.</td>
<td>2015</td>
<td>0.5</td>
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#### Oral presentations

<table>
<thead>
<tr>
<th>Title</th>
<th>Year</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>High potential in ball sports from the perspectives of elite players and their youth trainers: a qualitative study. 21th Annual Congress of the European College of Sport Science; 2016 Jul 8, Vienna, Austria.</td>
<td>2016</td>
<td>0.5</td>
</tr>
<tr>
<td>Can Perceptuo-Motor Skills Assessment Outcomes in Young Table Tennis Players (7-11 years) Predict Future Competition Participation and Performance? An Observational Prospective Study. Science and Engineering Conference on Sports Innovations; 2016 Apr 8, Amsterdam, The Netherlands.</td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>Wereldtoppers en hun jeugdtrainers over het concept 'high potential' en de 'route to excellence' voor balsporten – een kwalitatieve studie. VvBN Symposium 2016 'Presteren op Olympisch niveau'; 2016 Mar 18, Utrecht, The Netherlands.</td>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td>Profiling international elite youth table tennis players using a multidimensional approach. European Table Tennis Union's Coaching Seminar 2016, 2016 Jan 24-26, Budapest, Hungary.</td>
<td></td>
<td>0.5</td>
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<tr>
<td>Workshop 'Talent: Een zaak van scouten of scoren? – Een vernieuwde kijk op talentidentificatie', Nationaal Coach Congres 'The ROAD to RIO – De rol van de coach op weg naar een piekmoment.', 2015 Dec, Papendal / Arnhem, The Netherlands.</td>
<td>2015</td>
<td>0.25</td>
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<tr>
<td>Profiling international elite youth table tennis players using a multidimensional approach. Japan Table Tennis Association Sports Science and Medicine Committee International Meeting 2015, 2015 Sep 18-21, Tokyo, China.</td>
<td></td>
<td>0.5</td>
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<tr>
<td>Assessing personal talent determinants in young racquet sport players: A systematic review. 20th Annual Congress of the European College of Sport Science, 2015 Jun 24-27, Malmö, Sweden.</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Assessing personal talent determinants in young racquet sport players: A systematic review. 14th ISTFSports Science Congress, 2015 Apr 23-25, Suzhou, China.</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Diamonds in the rough... Symposium Bewegingswetenschappen 2014, 2014 Nov 27, Nijmegen, The Netherlands.</td>
<td>2014</td>
<td>0.25</td>
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<tr>
<td>Event</td>
<td>Description</td>
<td>Year</td>
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<tr>
<td>• Motor skills assessment to predict table tennis performance? – a longitudinal study. 19th Annual Congress of the European College of Sport Science; 2014 Jul 2-5, Amsterdam, The Netherlands.</td>
<td>2014</td>
<td>0.5</td>
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<tr>
<td>• The Dutch Talent Identification Assessment for table tennis; a reproducibility and validity study. 18th Annual Congress of the European College of Sport Science, 2013 Jun 26-29, Barcelona, Spain.</td>
<td>2013</td>
<td>0.5</td>
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<tr>
<td>• Revision of two test items of the Dutch talent identification assessment measuring ball control in young athletes; a validity and reproducibility study. 13th II TF - Sport Science Congress, 2013 May 11-12, Paris, France.</td>
<td>2013</td>
<td>0.5</td>
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<tr>
<td>• Knowing the twig is knowing the tree? Assessing motor skills as part of talent identification in table tennis. ENSEE, 2013 Oct, Groningen, The Netherlands.</td>
<td>2013</td>
<td>0.25</td>
</tr>
<tr>
<td>• Evaluation of an eye-hand coordination test for talent identification in table tennis; a validity and reproducibility study. 17th Annual Congress of the European College of Sport Science, 2012 Jun, Bruges, Belgium.</td>
<td>2012</td>
<td>0.5</td>
</tr>
<tr>
<td>• Evaluatie van een ooghand coördinatie test ten aanzien van het discriminerend vermogen bij talentvolle en minder talentvolle jeugdsporters. ’Vitale regio’ Saxion, 2012 Nov, Enschede, The Netherlands.</td>
<td>2012</td>
<td>0.25</td>
</tr>
<tr>
<td>• Presentatie bij congres ’Talentontwikkeling: lessen uit de wereld van de sport!’ van de Academie Mens &amp; Arbeid van Saxion, 2012 Oct 18, Enschede, The Netherlands.</td>
<td>2012</td>
<td>0.25</td>
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**Poster presentation**

- Evaluation of an eye-hand coordination test to discriminate between talents and non-talents. E-poster presentation (Young Investigator Award) at the 17th Annual Congress of the European College of Sport Science, 2012 Jun, Bruges, Belgium. 2012 | 0.5 |

**d) Other**

**Interview articles**

- Sportknowhow 15-1-2015 2015
- De Volkskrant 22-12-2014 2014
- Gelderlander 25-6-2014 2014
- EditieNL website
- Metro 24-6-2014
- NRC Weekend 1-11-2014
- Sax.nu 30-6-2014
- Sportgericht (6) 2013
- Sportknowhow 10-7-2014

**Radio interviews**

- Interview radio 2 24-6-2014 2014
- Interview radio Gelderland 23-6-2014
- Interview radio Unique 14-6-2014
- Interview radio fun 24-6-2014

**Television**

- EditieNL 25-6-2014 2014
### TEACHING ACTIVITIES

e) **Lecturing**

<table>
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<tr>
<th>Institution</th>
<th>Details</th>
<th>Years</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>Saxion University of Applied Science</td>
<td>Master Musculoskeletal, Research methodology and statistics.</td>
<td>2012-2016</td>
<td>12</td>
</tr>
<tr>
<td>Saxion University of Applied Science</td>
<td>Bachelor Physical Therapy (International Class), Qualitative research methods.</td>
<td>2015-2016</td>
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f) **Supervision of internships / other**

<table>
<thead>
<tr>
<th>Institution</th>
<th>Details</th>
<th>Years</th>
<th>Hours</th>
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<tbody>
<tr>
<td>Saxion University of Applied Science</td>
<td>Master Musculoskeletal, Supervision on Master Theses and Professional Case Studies.</td>
<td>2012-2016</td>
<td></td>
</tr>
<tr>
<td>Saxion University of Applied Science</td>
<td>Bachelor Physical Therapy, Supervision Bachelor Theses.</td>
<td>2015-2016</td>
<td></td>
</tr>
<tr>
<td>Avans+ University of Applied Sciences</td>
<td>Master Paediatric Physical Therapy, External examiner Master Theses.</td>
<td>2012-2016</td>
<td></td>
</tr>
<tr>
<td>HAN University of Applied Sciences</td>
<td>Bachelor Physical Therapy, External examiner research projects.</td>
<td>2015-2016</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Supervision Master Thesis T. van de Water focusing on talent development in badminton (University Medical Center Groningen / University of Groningen).</td>
<td>2015-2016</td>
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### ANCILLARY ACTIVITIES

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>Review scientific publication</td>
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<tr>
<td>International Table Tennis Federation, Sports Science &amp; Medical Committee, Full member.</td>
<td>2015 – present</td>
</tr>
<tr>
<td>Sports Medicine</td>
<td>2015 – present</td>
</tr>
<tr>
<td>Journal of Sports Sciences</td>
<td>2015 – present</td>
</tr>
<tr>
<td>Pediatric Exercise Science</td>
<td>2015 – present</td>
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### TOTAL ECTS

<p>| | |</p>
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<tr>
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<tbody>
<tr>
<td>ECTS</td>
<td>51.5</td>
</tr>
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</table>
Lieve mama en papa, bedankt.
uitnodiging

voor het bijwonen van

de openbare verdediging

dino

in the  rou

searching for

high potential

in youth

table tennis players

Op donderdag 6 oktober 2016

om 14:30 uur precies

in de Aula van de

Radboud Universiteit Nijmegen

Comeniuslaan 2, Nijmegen

Na afloop bent u van harte welkom

op de receptie ter plaatse

irene Faber

Schadewijkpad 4, 7391 TJ Twello

06 200 30 686

i.r.faber@saxion.nl

Paranimpfen

Rogier A.D. Gerritsen

Gerben J. Faber

TT-diamonds@hotmail.com