Summary

A large number of children participate in sports and physical activity on a day-to day basis and gain considerable health, social, athletic and overall development benefits in doing so. Therefore, it is important to maximize the amount of children and adolescents that are involved in sports through a better understanding of the pathways that lead to successful sports involvement. Previous research has shown that there is a positive association between a child's motor competence (= the ability to develop a wide range of motor skills), physical fitness and sports participation. Therefore, improving motor competence in all children might be important in getting them involved in sports. Since children with a better motor competence are able to perform a more varied range of motor skills, they might be able to successfully participate in a broader range of sports, which could possibly prevent burnout, overuse injury and thus drop out from sports. Therefore, this thesis focused specifically on motor competence development and the early diversification-specialisation trade-off as underlying factors of successful sports involvement.

To help understand the role motor competence might play in getting children involved in sports, a first study aimed to establish the KörperkoördinationsTest für Kinder (KTK) as a motor competence assessment instrument . Therefore, it investigated convergent validity between the KTK and another popular motor competence assessment instrument: the Bruininks-Oseretsky Test of Motor Proficiency – 2 in 6-12 year old children. This study showed that the KTK is a valuable tool for assessing motor competence. However, it is advised that more than one test be used, especially when profiling the motor competence of children with low motor competence. A second study investigated changes in motor competence in 6-12 year old children from 6 age cohorts over a two-year time span and revealed that motor competence might be less sensitive to change later in childhood. Finally, a third study measured changes in physical fitness and sports participation between children with a low, average and high motor competence. Children with a high motor competence consistently outperformed the rest of the sample and participated in sports more often.

In the next section of this thesis, the emphasis is on the early specialisation versus early diversification debate as a factor influencing successful sports involvement. A first study investigated differences in anthropometry, physical fitness and gross motor coordination between 6-12 year old children who participate in one or more than one sport. Diversifying children showed a better fitness and motor competence than those who participated in just one sport. The last two studies investigated the existence of field position specific differences in physical performance in youth handball and rugby union and showed that even at a youth level, children playing at different field positions, have significantly different performance profiles.

In conclusion, the research in this thesis acknowledges the importance of motor competence development and a diversification-specialisation trade-off in the pathways leading to successful sports participation in children and adolescents.

Samenvatting

Een groot aantal kinderen zijn dagelijks betrokken bij sportieve activiteiten en halen hier voordelen uit op vlak van gezondheid, sociaal functioneren, sportieve prestaties en algemene ontwikkeling. Daarom is het belangrijk dat men zoveel mogelijk kinderen en adolescenten aan het sporten kan krijgen en houden door middel van een beter begrip van de onderliggende factoren die leiden tot succesvolle sportparticipatie bij alle kinderen. Eerder onderzoek toonde reeds aan dat er een positief verband bestaat tussen de motorische competentie (zijnde de mogelijkheid om een breed bewegingsrepertoire te ontwikkelen), fysieke fitheid en sportparticipatie van jonge kinderen en volwassenen. Daarom is het belangrijk dat men de motorische competentie als een factor beschouwt die het succesvol aan sport doen kan beïnvloeden. Daarenboven is ook de wisselwerking tussen diversificatie en specialisatie een belangrijke beïnvloedende factor aangezien kinderen die een betere motorische competentie hebben en aldus een groter bewegingsrepertoire bezitten, makkelijker actief kunnen zijn binnen een brede waaier aan sporten en deze diversificatie werd reeds geassocieerd met een beperking van de burn-out, overbelasting en een gereduceerd staken van de sportieve activiteit bij jonge sporters.

Om de rol die de motorische competentie speelt in het betrokken raken en blijven bij sportieve activiteiten voor kinderen, peilde een eerste studie naar de hanteerbaarheid van de KôrperkoördinationsTest für Kinder (KTK), een vaak gehanteerd meetinstrument voor motorische competentie. In deze studie werd de convergente validiteit van deze testbatterij en een andere frequent gebruikte batterij voor het meten van de motorische competentie (Bruininks-Oseretsky Test of Motor Proficiency – 2) na gegaan bij kinderen tussen 6 en 12 jaar. Hierin werd aangetoond dat de KTK een zeer goed hanteerbare test is, doch wordt aangeraden deze test samen met een andere test te gebruiken, vooral omwille van de kans op meetfouten bij kinderen met een heel lage motorische competentie. In een tweede studie werd de motorische competentie van 6 leeftijdscohorten tussen 6 en 12 jaar gedurende twee jaar opgevolgd. Hieruit bleek dat er grotere veranderingen in de motorische competentie zijn bij kinderen tot 11 jaar dan erna. In een laatste studie werden de veranderingen in fysieke fitheid van tussen kinderen met een lage, hoge en matige fysieke fitheid gemeten. Hieruit bleek dat kinderen met een hogere motorische competentie ten allen tijden beter scoorden dan kinderen met een lage of matige motorische competentie. Daarenboven deden kinderen met een hogere motorische competentie vaker aan sport.

In het tweede deel van deze thesis wordt de aandacht verlegd naar het specialisatie-diversificatie debat aangezien een wisselwerking tussen beide een belangrijke factor zou kunnen zijn bij de ontwikkeling van succesvolle sportparticipatie. Uit een eerste studie die peilde naar de verschillen in antropometrie, fysieke fitheid en motorische competentie tussen kinderen die slechts één en kinderen die meer dan één sport beoefenden bleek dat kinderen die in meer sporten actief waren een beter fitheid en motorische competentie bezaten dan kinderen die slechts één sport beoefenden. Tot slot peilden de twee laatste studies naar de prestatieverschillen tussen adolescente rugby en handbal spelers van verschillende veldposities. Uit dit onderzoek bleek dat in beide sporten, jongeren uit de jeugdreeksen reeds een positie specifiek prestatieprofiel hadden eigen aan de positie waarop ze speelden. Dit onderzoek onderstreept het belang van motorische competentie en de wisselwerking tussen specialisatie en diversificatie in de ontwikkeling van succesvolle sportparticipatie bij kinderen en adolescenten.

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PART 1: GENERAL OVERVIEW

A. General introduction

In order to describe and understand pathways leading to successful youth and adult sports involvement, a definition of ‘successful sports involvement’ is paramount. Throughout the course of my PhD project at Ghent University, I’ve had the chance to work with a large number of children and adolescents and I’ve learned that successful sports involvement isn’t merely about attaining the highest standards of performance. Some of the children I’ve been fortunate to work with were very proficient in their respective sports, while others were not. However, regardless of the level at which these children participated, they all reported that the major reason why they were active, was because they enjoy playing sports. Some children liked the challenge or the inherent friendship and team play that come with sports participation, while others just enjoyed being physically active. Therefore, successful sports involvement does not seem to be the one-dimensional concept of attaining the highest standard. Rather, from my point of view, it seems to be a highly variable, multi-dimensional outcome of participation in sports where teamwork, enjoyment, progression, performance at an individual-appropriate level and social contact are of importance.

Recently, a boom in the amount of research on talent identification and development has led to a specific focus on those children who portray exceptional talents within their respective sports (Vaeyens et al., 2008). Children who are perceived as being ‘talented’ and destined for future success in sports are recruited at a young age for athletic development programs aimed at nurturing their talent. However, by only targeting talented children and adolescents, we are focusing on an estimated 5-10% (Gagné et al., 2004) of the young and active population. Hence, we are at risk of possibly excluding 90-95% of all (active) children that might also benefit from specialised development programs. In 2007, the Flemish Sports Compass used a physical activity questionnaire to estimate the amount of participation in (un)organised sports in the general Flemish Population. This questionnaire used in 2137 children from 6-12 years showed that 76% of these children participated in a sport, recreationally or competitively. This means that 76% of our Flemish children benefit from the social, cultural, health and skill acquisition benefits of sports participation. It also means that economical incomes (through memberships, merchandising, volunteering, etc.) are generated through sports participation for 76% of the children between 6-12 years. Therefore, it is in the interest of both sports and its governing bodies to provide all children, and not just the individuals perceived as being talented with an optimal management of their successful sports involvement. It is for this particular reason that I believe the development of outstanding performances and the promotion of sports participation in a general population of children should be addressed using the same basic principles. However, the methods used to aid individuals need to be in accordance with the goals set for specific groups of children. It is in this regard that the research presented in this thesis aims to better understand the factors that lead to successful sports participation for children and adolescents of all participation levels. To clearly understand how this thesis might contribute to understanding pathways leading to successful sports involvement, I propose the following model in figure 1. This model contains elements of models that will be discussed further on in this dissertation.

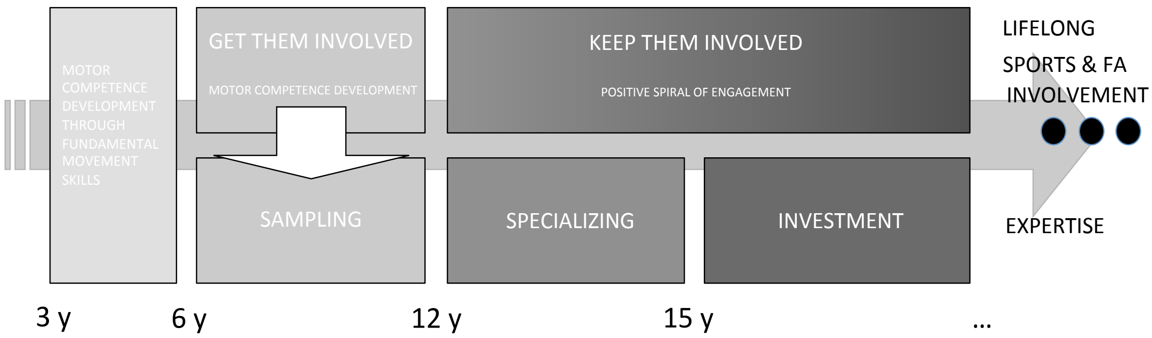

Figure 1: Model for the development of successful sports involvement based on models by Côté et al. (1999) and Stodden et al. (2008)

Fundamental Movement Skills stage

In this model for the development of successful sports involvement, there is a fundamental movement skill phase before the age of 6 years. Fundamental movement skills are considered the building blocks of future physical activity and sports participation and are made up of three components: stability, locomotion and object manipulation (Gallahue & Ozmun, 1995) that consist of skills such as balancing, turning, jumping, climbing, rolling, kicking, hopping among others. Previous research has reported that a child that is not able to master certain fundamental movement skills is far more likely to be less physically active, which may in turn lead to increased sedentary behaviour and health issues (Skard & Vaglum, 1989). Hence, the emphasis in this model for the development of future successful sports involvement between the ages of 3 and 6 years is on the development of fundamental movement skills.

'Get Them Involved'

In the second stage of this model (6-12 years), the emphasis is on getting children involved in sports participation and physical activity. In order to promote sports participation in children, it is important to understand that children do not only the require building blocks for future sports participation, they also require the capacity to develop a movement repertoire that allows them to be active in a broad range of physical activities (Garcia et al., 2002). Castelli en Valley (2007) used the term 'motor competence' to describe this particular ability. Mastering a large array of movements (e.g. being motor competent) will allow children to be active in different sports and different physical activities, which might be beneficial for the development of expertise and/or a lifelong adherence to physical activity (Côté et al., 2009). Furthermore, Stodden et al. (2008; 2009) mentioned that motor competence might lead to an increased participation in physical activity and as a result increased fitness and increased motor skill development. Stodden et al. (2008) called this phenomenon the 'positive spiral of engagement'. Chapters I, II and III in this dissertation use the 'get them involved' phase in this model as a framework.

'*Keep them involved'*

Finally, the third phase in this model is concerned with the engagement in physical activity and sports in 12-18 year old individuals. This stage is called the 'Keep them involved' stage and should lead to a lifelong adherence to sports as an expert, recreational participant, coach, volunteer etc. The 'Keep them involved' stage consists of two different pathways leading to different outcomes. In this stage, the emphasis is on the opportunity for each individual to participate in sports on a suitable level since children and adolescents who perceive themselves to be competent in a certain activity/behaviour and therefore feel successful, are more likely to persevere (Weiss & Ferrer-Caja, 2002). The outcome for this pathway is the lifelong participation in sports physical activity, with special emphasis on health and enjoyment. The second pathway in this stage of the development of sports involvement is the pathway leading from novice to expert performance and is based on the Developmental Model of Sports Participation (DMSP, Côté et al., 1999) The DMSP consists of a gradual increase in specialised training with age, leading to the development of expertise in one sport (Côté et al., 1999). Chapter IV in this dissertation uses this stage as a framework.

Output: successful sports participation for everyone

In this model, two outputs for successful sports involvement are apparent. Both outputs should be seen as the outside of a continuum from the participation in recreational physical activity to the involvement in highly competitive sports. The first outcome of the model presented here is the attainment of expertise in a certain sports, which only a minority of all adolescents and/or adults will achieve. The second is a lifelong involvement in physical activity and sports. However, successful sports involvement means that any individual should be able to participate at an individually suitable level. Therefore, successful sports involvement will be anywhere along this continuum dependent on individual goals and abilities. It is also important to nuance that lifelong sports involvement could be any combination of the participation in physical activity and sports, the recycling of individuals for coaching or volunteering for various physical activity and sporting events/clubs.

B. Motor competence

1) General definitions

Physical fitness is the capacity to perform physical activity (Ortega et al., 2008) and can be categorized into health and performance related fitness. Health related fitness consists of physical and physiological components that directly affect health (Powell, 1998) such as cardiorespiratory fitness, muscular strength, muscular endurance and flexibility (Henderson and Sugden, 1992). Performance related fitness refers to those components of physical fitness that have a direct influence on performance. These components include muscular strength, cardiovascular endurance, speed and agility, and certain aspects of motor coordination (Powell, 1998). Children and adolescents use a combination of these aspects of performance-related physical fitness in order to successfully participate in any sport. For example, during a three-on-three game of backyard basketball, children use speed and agility to outrun and outmanoeuvre their opponents, explosive strength to perform a jump shot, cardiovascular endurance to recuperate from bouts of intensive running and hand-eye motor coordination while performing complex motor actions such as dribbling the ball at high speeds. Motor coordination is probably the least well known and definitely the most abstract aspect of the construct of physical fitness. Therefore, a definition of 'motor coordination' is important in understanding how it might directly influence performance and/or health.

Throughout the literature, the term 'motor coordination' is often used interchangeably with 'motor competence'. However, there is a strong nuance between both. Motor coordination specifically refers to the synergies between muscles or muscle groups that allow for the fluent execution of a purposeful movement (Magill, 2007) while motor competence is the ability to execute a wide range of motor actions and therefore relies on adequate levels of motor coordination and physical fitness in order to do so. Hence, in order for children to confidently perform a wide range of motor actions in every-day life (e.g. for children to be motor competent), they must possess adequate levels of motor coordination as well as physical fitness. For a short summary of the terminology used in this dissertation, please refer to the glossary in Table 1.

Table 1: Glossary for the most frequently used terms in this thesis (Magill, 2007)

Terminology used	Definition
Motor Actions/Skills	*Activities or tasks that require voluntary head, body, and/or limb movement to achieve a goal*
Motor Coordination	*Synergies between muscles or muscle groups that allow for the fluent execution of a purposeful movement*
Gross Motor Coordination	*Synergies between muscles or muscle groups that allow for the fluent execution of a purposeful movement involving large musculature*
Fine Motor Coordination	*Synergies between muscles or muscle groups that allow for the fluent execution of a purposeful movement involving small musculature*
Fundamental Movement Skills	*Motor skills (balance, locomotion, object control) that are considered the building blocks of future physical activity and sports participation*
Motor Competence	*The ability to execute a wide range of motor skills/actions*

Not only does motor competence refer to a child's ability to develop a movement repertoire, but is has also been hypothesized that the ability to efficiently learn and master new skills, is largely dependent on a child's motor competence (Henderson and Sugden, 1992). Motor competence has been shown in earlier research to be critically sensitive to change before the age of

12 years (Borms, 1986; Gallahue and Donnely, 2007). Therefore, any sports participation development model involving children should at least acknowledge the importance of motor competence during this 'sensitive window'. An adequate motor competence allows children to comfortably master the movements they need to participate in every-day physical activity (Henderson and Sugden, 1992) and is also a necessary prerequisite for an optimal talent development in children that show outstanding movement potential (Abbott, 2002). Furthermore, the early identification of children with below-average motor competence facilitates an early rehabilitation in this particular group using specific intervention programs (Haga, 2009, Bardid et al., 2013). This thesis specifically investigates the validity of a commonly used motor competence assessment instrument (KörperkoördinationsTest für Kinder (KTK); Kiphard and Schilling, 1974), the possible existence of a plateau phase in changes in motor competence before the age of 12 years and the effect of a relatively low or high motor competence on physical fitness and sports participation in children in this first (please consult section 'C' of this introduction for further explanation on the pathways to successful sports involvement) stage of athlete development (6-12 years).

2) Measuring motor competence

2.1 KTK versus other motor competence testing batteries

Motor competence is the ability to master and perform a wide array of motor skills. However, measuring this ability per se is difficult. Therefore, motor competence testing batteries were designed to measure the proficiency in performing different motor skills (performing motor skills under time-constraints, quality of movement while performing a motor skill, etc.) and hence conclude on a person’s motor competence. Throughout years of research, many motor competence assessment instruments have been developed and used. It is not in the scope of this thesis to describe all of them - for an elaborate review please consult Cools et al. (2008). However, describing some of the characteristics of the most commonly used testing batteries will help to explain why, in this thesis, one instrument in particular was used to measure motor competence. First of all, motor competence testing batteries have been designed with different goals in mind. Some instruments were designed to be used in educational setting (Motoriktest für vier-bis sechsjärige Kinder: MOT 4-6 - Zimmer and Volkamer, 1987), others aim to specifically identify children with movement difficulties (Bruininks-Oseretsky Test of Motor Proficiency: BOT-2 – Bruininks and Bruininks, 2005; Movement assessment battery for children: M-ABC; M-ABC-2– Henderson and Sugden, 1992; 2007; Peabody Developmental Scales Second Editions: PDMS-2 – Folio and Fewell, 1983; Test of Gross Motor Development Second Edition: TGMD-2 – Ulrich, 1985; Maastrichtse Motoriek Test: MMT – Vles et al., 2004) while others can be used in a more general population of children (KTK; Kiphard and Schilling, 1974). More specifically, the KTK, MOT 4-6, BOT-2 and TGMD-2 were designed to measure changes in motor competence over time, the PDMS-2 and TGMD-2 aim to assess the effectiveness of interventions for children with or without disabilities and the MMT was specifically designed to identify children with Attention Deficit Disorder. Secondly, these commonly used batteries are designed for the use in different age groups. PDMS-2 is designed to evaluate motor competence from birth to six years while the MOT 4-6 and MMT can only be used between four and six years. TGMD-2 targets children between three and ten years old and M-ABC can be used between six and twelve years. In 2007, a renewed version of the M-ABC, the M-ABC-2 was developed (Henderson and Sugden, 2007) which can be used in children from 3-16 years. Therefore, the only testing batteries that cover a larger age span are BOT-2 (4-21 years), M-ABC-2 (3-16 years) and KTK (5-14 years). Third, the abovementioned instruments consist of different numbers of subtests and take a different amount of time to be completed per child. The MOT 4-6 has 18 items and takes the least amount of time to be completed (15-20 minutes per child). The longest completion times were reported for MMT (70 items, 30 min), BOT-2 (53 items, 45 min) and PDMS-2 (249 items, 45 min). M-ABC (8 items), M-ABC-2 (8 items), TGMD-2 (12 items) and KTK (4 items) took 20 minutes per child to be completed (Cools et al., 2008). Finally, the KTK uses the same test items for all age groups. This allows for an easy long-term follow up and has some practical advantages like an easy education for test leaders and a single standardized protocol for all test samples. Other batteries covering a large age span: BOT-2 (e.g. knee push-ups versus regular push-ups in different populations) and M-ABC II do have different tests for different age bands and therefore lack the practicality the KTK has in this matter. Based on these findings, the KTK can be used in a general population with a wide age range and consists of only four items that take 20 minutes to be administered. A summary can be found in table 2.

Table 2: Summary of goals, age-range, items and duration for several motor competence assessment instruments

Battery	**Setting**	**Age-range (yrs)**	**Items**	**Duration (min)**
MOT 4-6	Educational	4-6	18	15-20
BOT-2	Identify Movement Difficulties	4-21	53	45
M-ABC-2	Identify Movement Difficulties	3-16	8	20-30
PDMS-2	Identify Movement Difficulties	0-6	249	45
TGMD-2	Identify Movement Difficulties	3-10	12	20
MMT	Identify Movement Difficulties	4-6	70	30
KTK	General	5-14	4	20

2.2 KTK and skill classification

The KTK consists of four subtests aimed at measuring motor competence: 1) Jumping Sideways (JS) 2) Moving Sideways (MS), 3) Hopping for Height (HH) and 4) Balancing Backwards (BB). In JS, participants jump sideways on a mat over a small slat for 15 seconds for two trials. The total number of jumps in the two trials is summed and counts as the final score. In MS, the participants move sideways by stepping on and transferring two 25 cm^2 boards on the floor. The number of repetitions over two 20 s trials is the final score for this test. For the HH test, participants jump on one leg over an increasing pile of 5 cm high foam pillows. Before and after this jump, two hops one the same leg are required. Participants receive three, two or one point(s) when succeeding in one, two or three trials. The points collected for each leg are summed and used as the final score for this test. Finally, in BB, participants walked backwards on increasingly thin balance beams (6 cm, 4.5 cm, 3 cm) for a maximum of three steps per one of three trials on each beam. The total amount of steps over three trials on each beam was used as the final score.

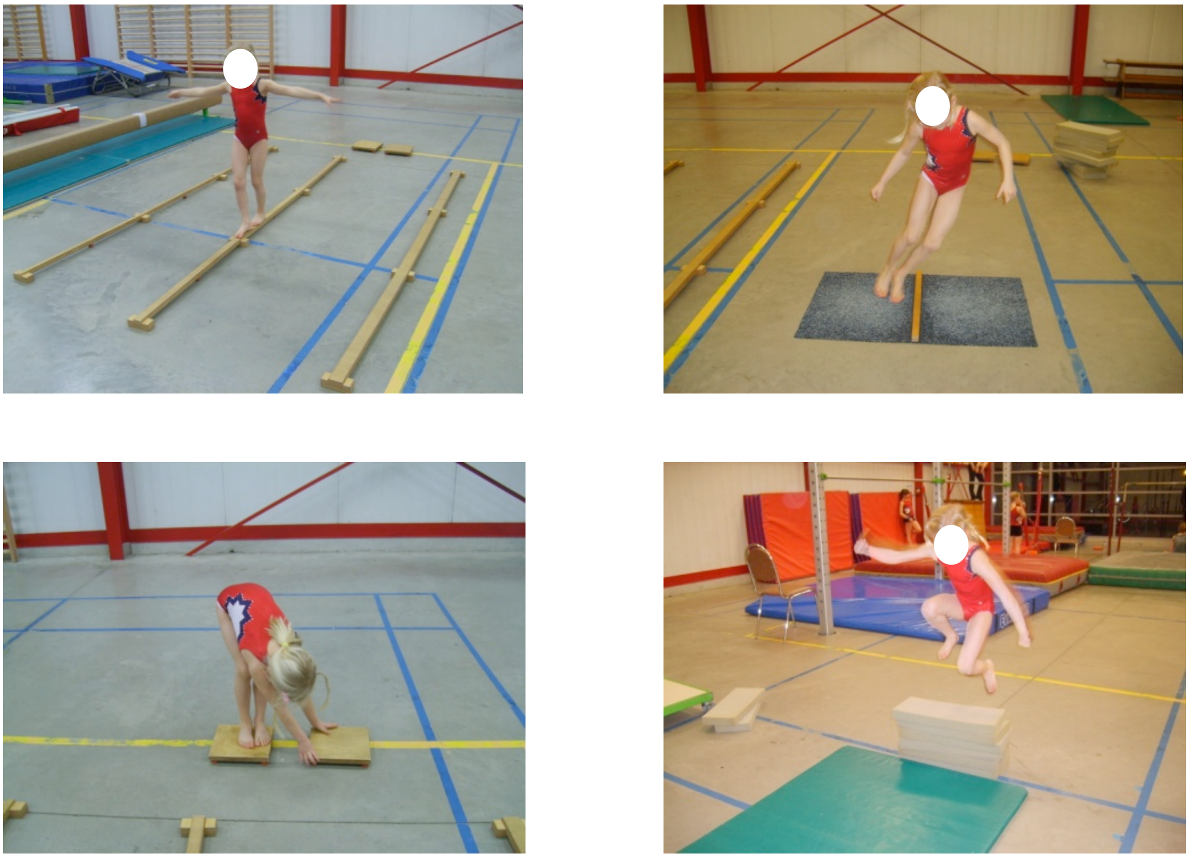

Figure 2: the KTK subtests Balancing Backwards (top left), Jumping Sideways (top right), Moving Sideways (bottom left) and Hopping for Height (bottom right)

To further elaborate on the applicability of the KTK in a sports and physical activity context, a classification of the motor skills used while performing the KTK is necessary. A commonly used system to classify motor skills is the one-dimensional system (Magill et al., 2007). Every skill can be classified on a continuum between gross and fine, discrete and continuous, and open and closed motor skills. Gross motor skills, as opposed to fine motor skills are skills using large muscles or muscle groups to achieve a goal. During sports participation, gross motor skills are more commonly observed than fine motor skills. Because of the large musculature used in all KTK subtests, they are to be situated on the gross motor skill side of the continuum, as is proposed by the KTK test manual (Kiphard and Schilling, 1974). Furthermore, because of the fact that the KTK subtests mainly involve gross motor skills, which are very common in sports, the test itself is highly applicable in a sports context. Continuous motor skills have arbitrary movement beginnings and end points and usually involve repetitive movements. Discrete skills are the opposite and have a clear beginning and end point. In the middle of this continuum are serial skills that can be described as a series of discrete skills. JS, MS and BB involve very repetitive movements that have unclear end and starting points and can therefore be classified as continuous motor skills. HH however, is clearly a serial skill that consists of a series of discrete skills (hop, hop, jump, hop, hop). Closed skills involve a stationary environment where the participant decides on movement initiation. Open skills involve an unstable and unpredictable environment where an object or environment is in motion and the environment ‘decides’ when to execute the skill. All KTK tests can be categorized as closed skills since the environment is stationary and the participants decide on movement initiation.

2.3) Psychometric properties of the KTK

A classification of the tests used in the KTK, however valuable, is only a first step towards the validation of this test battery. Hence, specific analyses on data collected by the KTK (and other testing batteries) are needed to provide conclusive evidence of validity and reliability that is required for scientific data collection. Reliability and validity need to be as complete as possible in order to understand what an assessment instrument is actually measuring and whether results from the instrument can be generalized. In the original testing manual (Kiphard and Schilling, 1974), content and internal structure validity of the KTK were respectively shown by a high explained variance on total KTK scores by the KTK subtests (explained variances ranged from 81% at 6 years to 98% at age 9) and by a factor analysis where all test items load on the same factor. Also, the ability to differentiate between typically and atypically developing children (91% were correctly labelled as having brain injury) was observed, showing good concurrent validity. However, convergent and discriminant validity, which are important aspects of construct validity, are not yet thoroughly established. Smits-Engelsman and colleagues (1998) showed low to fair correlations between M-ABC and KTK subtests for 208 children. However, conclusions on convergent or discriminant validity between the KTK and any other motor competence assessment instrument in a general population have not yet been made. A good reliability for the KTK was also reported through a test-retest reliability of the subtests between .80 ≥ r ≤ .96. The raw total score on the test battery had a test-retest reliability of .97. The KTK showed good internal consistency by showing strong significant relationships (.60≥ r ≤.81) between test items (Kiphard and Schilling, 1974). All available information on reliability and validity of the KTK can be reviewed in Vandorpe et al. (2011) and Cools et al. (2009). In summary, validity information is not complete since convergent and discriminant validity between the KTK and any other motor competence battery in a general population of children has not been thoroughly determined. Therefore, this thesis aimed to assess convergent and discriminant validity between KTK and BOT-2 Short Form because of the similarities in content between both batteries.

3) Changes in motor competence over time

3.1 Stages in motor development

In order to truly understand how motor competence levels in young children influence their everyday life and their ability to participate in physical activity or sports, we need to understand how motor competence develops between 6 and 12 years. From birth on, children go through different stages of motor development. The first post-natal stages involve involuntary movements and reflexes and are therefore out of the scope of this thesis on voluntary motor actions. The first purposeful actions involving large musculature are seen when children interact with the environment at an early age (pointing, flapping, gesturing, etc.). One of these actions is attempting to stand upright. Standing upright and learning how to balance (or lose and regain balance) are important prerequisites to engage in actions like kicking, throwing, jumping, and skipping (Gallahue and Donnely, 2007). Later on, children develop a large array of increasingly complex skills (Cratty et al., 1986), with increased efficiency and flexibility (Haywood & Getchell, 2005). Individual trajectories in the development of motor skills result in great inter-individual differences in the rate of motor development being observed in the general population (Parizkova et al., 1984). These inter-individual differences persevere when children start attending elementary school education. It is within a school context that many children are exposed to peer competition for the first time. While for some children this peer competition may enhance their motor development, it is daunting for others. This difference between children may then cause a further widespread variation in motor competence during elementary education.

3.2 Sensitive windows for motor competence

Different studies by Borms (1986) and Gallahue & Donnely (2007) hypothesized ‘a golden age’ for motor competence before 12 years during which a child can easily acquire new movement patterns. Unfortunately, no research has been able to clearly show changes in motor competence from early childhood well into adulthood. Mostly, this hiatus in research is caused by the inability to conduct longitudinal research or the inability to use a specialised motor competence assessment instrument. However, more recent research by Largo et al. (2001) on this ‘sensitive window’ hypothesis has been promising. This research group showed curves for timed performance (e.g. time to complete a set number of repetitions) on nine motor competence tests based. They suggested that around the age of 12, a performance plateau might limit the further development of timed performance. Furthermore, longitudinal research by Ahnert et al. (2009) measured developmental changes in motor competence from early childhood (4 years) into young adulthood (23 years) and concluded that motor competence increased with age, but improvements were far greater before the age of 12 than after.

3.3 Children with low motor competence

Since a large variance in motor competence is observed throughout childhood (Wrotniak et al., 2006), it might be worthwhile to observe differences between the extremes of the motor competence spectrum. On the low motor competence side, researchers have focused on the negative effects of low motor competence on physical fitness (Hands, 2008; Stodden et al., 2009), physical activity (Cairney, 2006; 2007; Okely et al., 2001), overweight (D'Hondt et al., 2012) and psychological concepts like self-worth and motivation towards sport (Rose et al., 1997; 1998; Vedul-Kjelsas et al., 2011). Cross sectional research has established a positive relationship between motor competence and health-related physical fitness in 9-10 year old children (Haga, 2009), 6th grade primary school children (Vedul-Kjelsas et al., 2011) and adolescents (Stodden et al., 2009) and revealed below average performances for low motor competent children on tests of flexibility, cardiovascular endurance, speed and agility and strength (Saakslahti et al., 1999; Hands and Larkin, 2006; Cairney et al., 2007; Cantell et al., 2008). Furthermore, a positive association between the level of motor competence, physical fitness and the participation in physical activity has been observed. It was hypothesized that children with a low motor competence are not sufficiently physically active, which might in turn result in lower physical fitness levels compared to children with high motor competence (Hands, 2008; Haga, 2009; Cairney et al., 2011). Also, a combination of poor physical fitness and low motor competence can contribute to early fatigue (Okely et al., 2001; Hands & Larkin, 2002) and thereby further limit opportunities to develop motor skills through playground play, after school sport and backyard activities. Okely et al. (2001) recognized that physical activity does indeed mediate the relationship between motor competence and physical fitness and Cairney et al. (2006; 2011) and Hands (2008) expressed their concern that children with low motor competence may continue to show decreased participation in physical activity over time, possibly resulting in a further decrease of physical fitness levels. This 'snowballing' effect has been called the 'negative spiral of engagement' (Stodden et al., 2008) and shows that a possible exclusion from physical activity in motor incompetent children might in time induce a snowballing effect resulting in augmented sedentary behaviour and compromised health. The abovementioned association between motor competence, physical fitness and physical activity was explained by Stodden et al (2008) in the model depicted below (Figure 3).

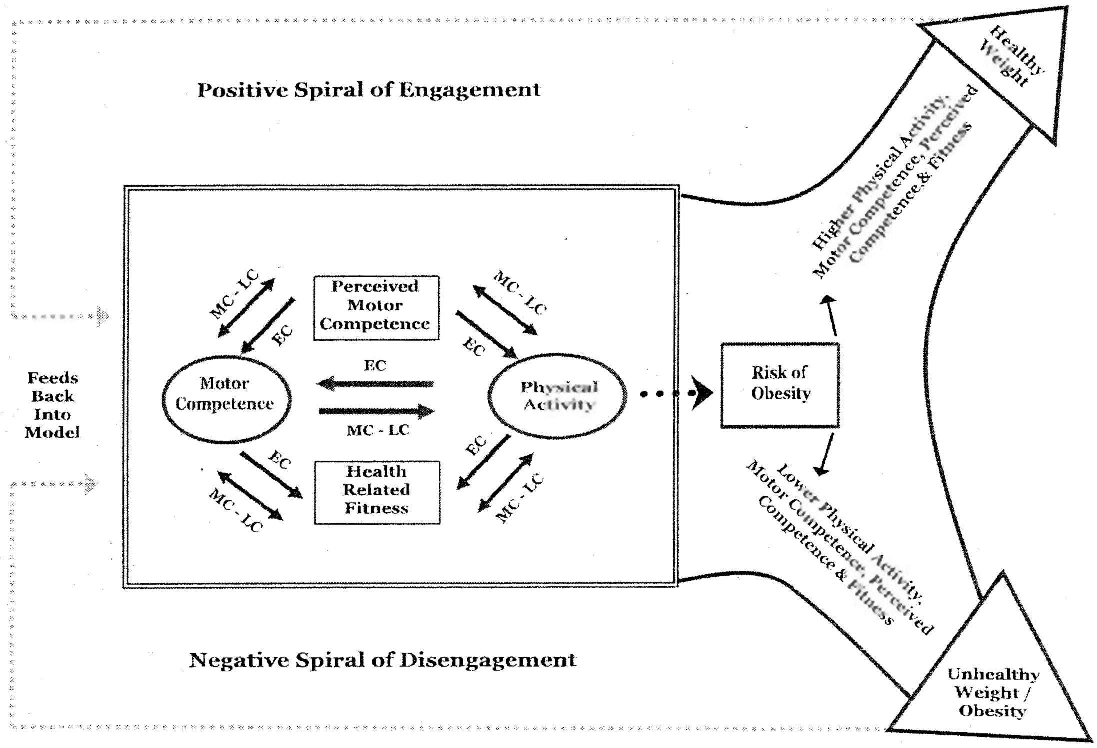

Figure 3: The 'Negative/positive spiral of (Dis)engagement' shows the relationship between motor (in)competence, physical (in)activity and (lack of) physical fitness (Stodden et al., 2008). Note: EC = Early Childhood, MC = Middle Childhood, LC = Late Childhood

In this model, the authors hypothesize that during early childhood, changes in motor competence are mainly driven by the engagement in physical activity. They suggest that increased physical activity in turn provides opportunities for motor competence and physical fitness development ('Positive spiral of engagement'). Therefore, children who are not frequently physically active are at risk of developing low motor competence and physical fitness levels ('Negative spiral of engagement'). The authors hypothesize that the relationship between motor competence, physical activity and physical fitness strengthens over time. This has direct consequences for fitness and health that further catalyse the negative or positive spirals, emphasizing the possible long-term negative effects of low physical activity, (perceived) motor competence and physical fitness on health.

3.4 Children with high motor competence

As mentioned before, there are large variations in motor competence in children and adolescents (Wrotniak et al., 2006): some children are clumsy while others perform a large variation of movements gracefully and efficiently. Understanding how these variations influence athletic development in a population of highly skilled children is paramount in order to provide these children with programs that suit their competence levels. The detection and identification of talented individuals has attempted to include measures of motor skill proficiency in testing batteries aimed at profiling performance characteristics in children and adolescents. This research finds its rationale in review studies such as Abott and Collins (2002) and Vaeyens et al. (2008) that stated that a one-dimensional conceptualization of talent would likely lead to a de-selection of many children. Rather, these studies recommend adopting a multi-dimensional approach to talent identification and development, which may include measuring motor competence. Vandorpe et al. (2012) showed that a non-sport-specific motor competence testing battery (KTK) was able to successfully predict short-term future performances in a group of highly skilled female gymnasts. Vandendriessche et al. (2012) advocated the use of the KTK for talent selection in youth soccer players because it appeared to be uninfluenced by maturation.

C. Pathways to successful sports participation: early specialisation vs early diversification

1) Sampling versus specialisation

Throughout research, two opposing approaches have been used to model athlete development from novice to expert: early specialisation and early diversification. Both of these approaches find their earliest roots in research on practice (in)variability (Schmidt, 1975) and stages of learning (Gentile, 1972). In his 'Schema Theory', Schmidt (1975) proposed that the variety of movement and context characteristics a person experiences while practicing a skill is a key predictor of future successful performance of a skill. Later research that compared constant (low practice variability) with variable (high practice variability) practice routines, concluded that while constant practice groups clearly showed performance improvements during practice, variable practice groups often showed superior results on a transfer or retention test (van Rossum, 1990; Barreiros et al., 2007; Porter and Magill, 2010). Furthermore, Gentile (1972) proposed three stages of learning: a cognitive stage, an associative stage and an autonomous stage. During the initial stages of learning, Gentile (1972) suggested that high practice variability was the best approach to learning new skills. These early ideas on practice variability have undoubtedly been the inspiration of the models used nowadays to describe pathways that lead to expert performances.

Many research groups have investigated the early diversification and early specialisation pathways to sports involvement with mixed results. The first support for a specialisation pathway to sports expertise came from Simon and Chase (1973). They concluded that the variation in performance between chess players was due to the quantity and quality of practice. They were the first to argue that organizing patterns of play into sizeable chunks was a direct result of training. This approach to the development of expertise has led to the 10-year-rule that states that 10 years of committing to the highest levels of training is the minimum requirement to attain expertise. This rule has been applied successfully in many cognitive domains (music, mathematics), but also in swimming (Kalinowski, 1985), distance running (Wallingford, 1975) and tennis (Monsaas, 1985). A progression on the ten-year-rule is the 10.000-hour-rule (Ericsson and Tesch-Romer, 1993) which still today is the prototypic approach to early specialisation. This research group proposed a combination of an early involvement in sports and the participation in 10.000 hours deliberate and structured practice as the way of developing expert performance. In se, this approach implies that the sooner one starts specialising in a single domain, the greater the chance of achieving expertise. Off course, such a performance-centred approach has its limitations. Wiersma (2000) hypothesized that the focus on a narrow set of skills during specialisation might limit the development of a wide range of motor skills (i.e. motor competence). This would inevitably lead to the development of a specific set of motor skills that suits a specific sport or aspect of a sport, which in turn might limit the potential of children to participate in other sports at some stage. Hence, using the early specialisation pathway to expertise as a guideline for the development of sports performance is extremely exclusive since it favours only those children that persevere in their specialised domain. Children that choose not to persevere in their original sport, or who are just not able to cope with the demands of highly competitive sports, are at risk of dropping out since their sport specific profile might not favour the participation in many other sports.

2) Developmental Model of Sports Participation

A more favourable approach to sports involvement from a developmental point of view is the early diversification pathway to expertise. One model used to describe this pathway is the Developmental Model of Sports Participation (DMSP, Côté, 1999; Côté et al., 2003, 2007; Côté & Fraser-Thomas, 2007) and proposes three developmental stages: the sampling stage (6–12 years), the specialising stage (12–15 years), and the investment stage (+15 years) (Figure 4). During the sampling stage, young athletes participate in various sports and engage in relatively unstructured deliberate play designed to maximize enjoyment. Meanwhile, children participate in sports through playful and relatively unstructured activities called 'deliberate play'. These activities are characterized by an enjoyment-centred approach using arbitrary and flexible rules of the game (Côté, 1999). Scientific support for the early diversification pathway has been provided by Baker and colleagues (2003, 2005), who reported that athletes in field hockey, basketball and netball who required fewer hours of sport-specific practice to attain expertise, had participated in many sporting activities prior to reaching an expert level. Furthermore, expert triathletes (Baker et al., 2005) had participated in more hours in different sports activities before starting triathlon than their non-expert counterparts. Also, Soberlak and Côté (2003) found that 6- to 8 and 9- to 12-year-old ice-hockey players participated in an average of three to six sports other than their primary sport during the sampling years. The advantage of using the diversification pathway to expertise as a guideline for the development of youth sports involvement in general is that it has a general stage (sampling stage) that all children, talented or not, are involved in. Hence, it allows all children to develop qualities that suit their specific levels of sports participation. A second advantage of the DMSP is that it provides children that do not show exceptional talent with an alternative to dropout and further specialisation. Following the sampling stage (12+ years), the DMSP proposed two different trajectories: 1) Children who do not show exceptional talent are introduced to recreational sports participation with a focus on enjoyment and health benefits. These children are encouraged to participate in sports that suit their personal level in an extended sampling stage. 2) 'Talented' children progress to a specialisation (12-15 years) and investment stage (+15 years) consecutively, with increasing amounts of specialised practice. At this age, physical, cognitive, social, emotional, and skill development reaches its peak and allows athletes to start highly specialised training in a single sport with the main goal of improving performance (Patel et al., 2002). However, it must be mentioned that because of the differences in ages at peak performance in different sports, it might not be easy to implement the early diversification pathway in sports where peak performance is attained at a relatively young age like gymnastics, figure skating and swimming.

It is important to recognise that even in these specialised stages of development, the training focus should not be on specialisation alone. There is still a significant amount of time and effort to be spent on overall athletic development (Bompa, 1999). Therefore, a considerable amount of time should be invested in continued sampling to assure a general development of athletic skills. The sampling in the specialisation and investment stages can consist of the introduction of secondary training stimuli (strength and conditioning, running coordination training, etc.), the development of an all-round position in team sports or the combination of a winter and summer sport. Therefore, this thesis investigates the effect on sampling more than one sport on physical fitness and motor competence in a general sample of Flemish children and will investigate possible disadvantages of implementing position-specific specialisation in one sport in at a particular stage of athlete development in youth team handball and youth rugby union.

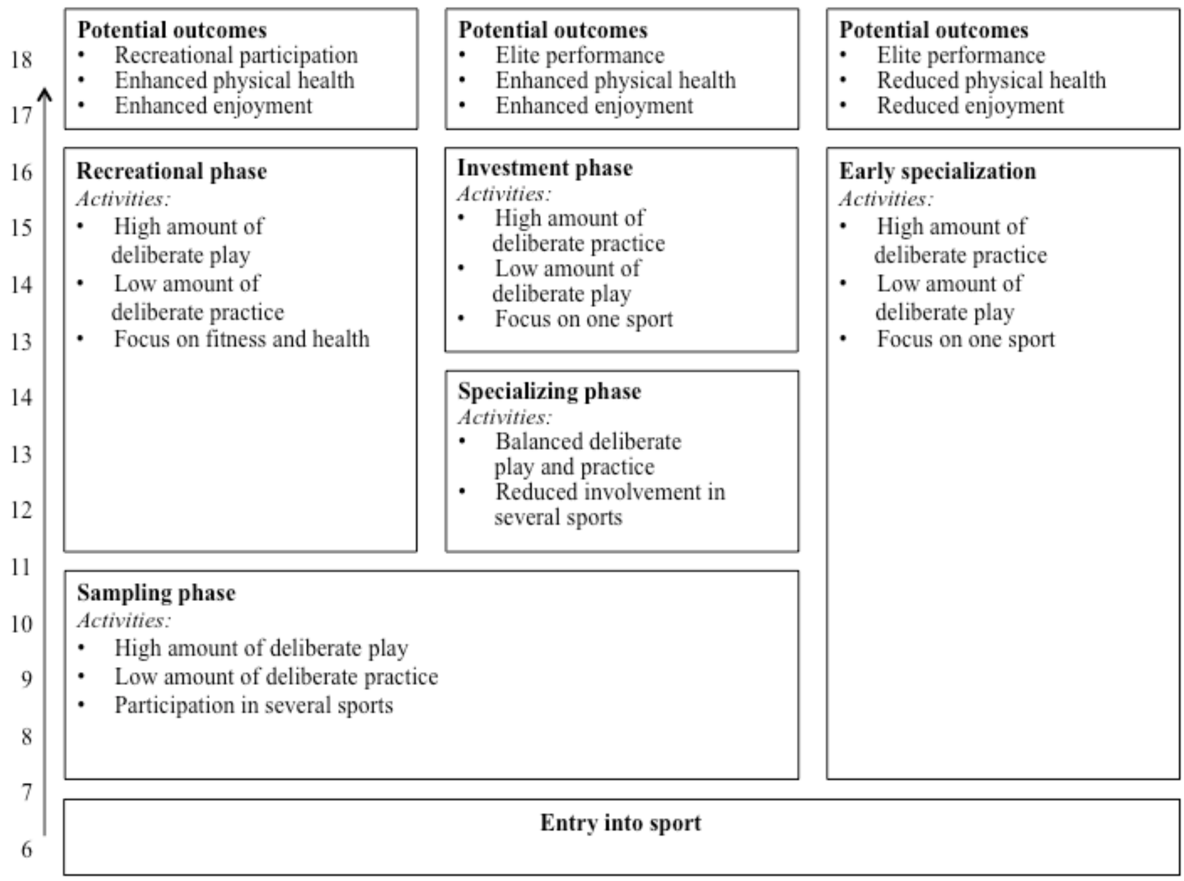

Figure 4: Developmental Model of Sports Participation (DMSP, Côté, 1999; Côté et al., 2003, 2007; Côté & Fraser-Thomas, 2007)

PART 2: OBJECTIVES AND OUTLINE OF THE THESIS

A. General outline

The pathway from early childhood sports involvement to future adult sports involvement is long and the risk of drop out is high when children and adolescents feel they can no longer manage the demands of a particular sport or when adolescents burn out because of a long-term investment in one particular sport (Gould et al., 1996). It is in the interest of governing bodies, sports clubs and the individual itself to keep as many people involved in sports as possible, as every person involved in sports generates considerable revenue and involvement in sports has been positively associated with physical health, mental health, self-worth, etc. (Sallis et al., 2000). Therefore, to understand the pathways leading to successful sports involvement, this thesis focuses on two major aspects: motor competence development and the early specialisation versus early diversification pathway. The first will be the topic for the first section of this thesis while the latter will be described in the second part.

1) Objective 1: The role of motor competence

First of all, this thesis aims to investigate the role motor competence might play in childhood athletic development. To do so, we need to understand how to measure motor competence. The KTK could be the appropriate motor competence assessment instrument to be used in scientific research and sports practice, as it is short and easy to administer. Although validity and reliability of

KTK are well established, convergent and discriminant validity specifically have not been thoroughly shown and would undoubtedly add to the overall usefulness of the KTK. Therefore, one of the research questions in this dissertation is whether the KTK is a valid instrument to be used assessing motor competence in all children (Chapter I). Specifically, the aim was to assess convergent and discriminant validity between the KTK and another popular motor competence testing battery: the short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-S Short Form). It is expected that convergent validity between the KTK and BOT-2 Short Form is only moderate as both batteries measure different aspects of motor competence (competency in gross motor skills = KTK; versus gross and fine motor skills = BOT-2 Short Form) and the normative samples used for deriving standardized scores in both batteries are different.

Once it is established that the KTK has excellent practical and scientific use, this testing battery can be used to describe the changes in motor competence over time in children aged 6-11 years. In the last few decades, researchers have attempted to find 'sensitive windows' for motor competence throughout youth athletic development. Although growth curves have been established for many physical fitness variables, this has not been done for motor competence. It has been hypothesised that there is a 'sensitive window' before the age of 12 years when motor competence might be particularly sensitive to change. Therefore, this thesis used a two-year follow-up study of 6-11 year old children to establish if there is indeed a sensitive window for motor competence and what age changes in motor competence might stabilise (Chapter II).

Finally, previous research has shown that children with low motor competence are at risk of having lower fitness levels and being less physically active than children with high motor competence. It was in the aim of this dissertation to investigate whether this negative association between motor competence, physical activity and physical fitness would be apparent in a general population of 6-10 year old children. Furthermore, earlier research mentioned that this negative association might result in increased sedentary behaviour, which might in turn negatively affect health (Stodden et al., 2008). Therefore, it was deemed important that this thesis followed these 6-10 year old children over a period of two years to investigate whether a possible negative effect of low motor competence on physical fitness and sports participation would persist in time, worsen or possibly disappear (Chapter II). We expected that highly competent children would outperform their peers with a relatively low motor competence at all times and that these differences would not disappear over time. Also, children with high motor competence would spend more hours participating in sports per week than their peers with low motor competence and these differences would increase in time.

2) Objective 2: Early specialisation versus early diversification

Children move through different stages of sports involvement throughout their life. The succession of these stages or which model should be used for development of sports involvement has been heavily debated in scientific research. In short, two major pathways to expertise have been used over the last decades: early specialisation and early diversification. Since only the latter includes all children in its model, talented or not, and provides a gradual progression to expertise through different developmental stages, it was the aim of this thesis to investigate this particular pathway. First of all, in chapter III, this dissertation aimed to describe differences in physical fitness and motor competence between children involved in more than one sport (e.g. 'sampling') and children who participated in one sport only (e.g. 'specialising'). It was hypothesized that children who participate in more than one sport would have better physical fitness and motor competence and that this 'sampling' effect would only be apparent in the oldest age group in the study (10-12 years).

Second, the early diversification model used in this dissertation states that children who progress from the sampling stage to the next stage of development have two options. 'Talented' children move on to a more specialised stage of training (while still spending considerable amounts of time sampling), while 'less talented' children remain in a sampling stage, where the focus is on enjoyment generating health benefits. Regardless of the pathway children end up in, it is believed to be important that children continue to sample. This will allow them to have a more diversified physical profile, which might help them to transfer their talents to other sports, be involved in other sports in case of drop out from their main sport, play different field positions or tackle different disciplines within one sport. This doctoral thesis wanted to specifically describe the actual situation concerning position-specific specialisation in two different team sports: team handball and rugby union (Chapter IV). Therefore, it is of interest to this thesis to know whether children playing at different field positions in team handball and rugby union have significantly different performance profiles as that would mean that these children might be starting a highly specialised training program early in their overall athletic development. We expected that due to a high-degree of position-specific training from 12 years on, performance profiles in youth handball and rugby union would be different across field positions.

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PART 3: ORIGINAL RESEARCH

CHAPTER I: MOTOR COMPETENCE ASSESSMENT

STUDY 1:

Motor competence assessment in children: convergent and discriminant validity between the KTK and BOT-2 Short Form testing batteries

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Abstract

This study investigated convergent and discriminant validity between two motor competence assessment instruments in 2485 Flemish children: the Bruininks-Oseretsky Test of Motor Proficiency 2 Short Form (BOT-2 Short Form) and the KTK. A Pearson correlation assessed the relationship between KTK and total BOT-2 Short Form, gross and fine motor composite scores in three age cohorts (6-7, 8-9, 10-11 years). Crosstabs were used to measure agreement in classification in children scoring below percentile 5 and 15 and above percentile 85 and 95. Moderately strong positive (r = .44-.64) associations between KTK Motor Quotient and BOT-2 total and gross motor composite scores and weak positive correlations between KTK Motor Quotient and BOT-2 Short Form fine motor composite scores (r = .25-.37) were found. Levels of agreement were fair to moderate. Therefore, some proof of convergent and discriminant validity between BOT-2 Short Form and KTK was established in this study.

Introduction

The ability to execute a wide range of motor acts, often described as motor competence, is a prerequisite for enjoyable and successful participation in leisure and sports activities from childhood into adulthood (Barnett et al., 2009; Cools et al., 2010). Within a general paediatric population, there is great variation in motor competence levels. Research shows that children who possess low levels of motor competence perform below average for their age and/or gender on different components of physical fitness (Hands & Larkin, 2006; Schott et al., 2006; Cairney et al., 2007) and show a greater decrease in physical fitness levels over time (Hands, 2008). Hence, they are unlikely to catch up with their more competent peers with age (Hands, 2008) and might be at risk of having a compromised physical fitness throughout adulthood (Stodden et al., 2009). Therefore, an early detection and continuous monitoring of children with low motor competence levels relative to their peers and/or normative standards is important.

In order to profile motor competence levels in children, different assessment tools have been used (Cools et al., 2008). Research on the assessment of motor skill competence in children has mainly focused on discriminating atypically developing children from their typically developing peers (Yoon et al., 2006). Therefore, most assessment tools have the specific goal of identifying children with motor problems (Cools et al., 2010). The Bruininks-Oseretsky Test of Motor Proficiency second edition (BOT-2; Bruininks & Bruininks, 2005), for example, is used to identify individuals aged 4-21 years with mild to severe motor problems. The BOT-2 testing battery measures fine and gross motor coordination using 53 test items in 8 subtests: fine motor precision (7 items), fine motor integration (8 items), manual dexterity (5 items), bilateral coordination (7 items), balance (9 items), running speed and agility (5 items), upper limb coordination (7 items) and strength (5 items). The BOT-2 Short Form (Bruininks & Bruininks, 2005) is a motor competence testing battery originally designed to identify 4-21 year old individuals with mild to severe motor problems. It is derived from the BOT-2 and is shorter and easier to administer and features a total 14 items, with at least one from each of the BOT-2 subtests. A second motor competence assessment tool of interest to this study is the KTK (Kiphard & Schilling, 1974; 2007). The KTK consists of four subtests and was developed with the main goal of identifying 4-15 year old children with mild to severe motor problems. More recently, it was also used for talent detection and identification purposes (Vandorpe et al., 2011; Vandendriessche et al., 2012).

To assess motor competence in children, there is a need for reliable and valid instruments. For the BOT-2 short form including knee-push ups, a very high inter-rater reliability of r = .98 and a test-retest reliability over a time interval of 7-42 days of r ≥ .80 were found as well as a good (r ≥ .80) internal consistency in 8-12 year old children. Content validity was shown by a high correlation (r = .80) between the BOT-2 Short Form and the BOT-2 Complete Form (Bruininks & Bruininks, 2005; Deitz et al., 2007). For the KTK, the scores on each subtest had a test-retest reliability of .80 ≥ r ≤ .96 and the raw total score on the test battery had a test-retest reliability of .97. The KTK showed good internal consistency by showing strong significant relationships between test items (.60≥ r ≤.81). To establish validity of the KTK, different aspects of construct validity were used. Construct validity is the evaluation of the extent to which a measure assesses the construct it means to measure and consists of content, internal structure, convergent and discriminant validity (Strauss & Smith, 2009). Content and internal structure validity were respectively shown by a high explained variance on total KTK scores by the KTK subtests (explained variances ranged from 81% at 6 years to 98% at age 9) and by a factor analysis where all test items load on the same factor. The ability to differentiate between typically and atypically developing children (91% were correctly labelled as having brain injury) showed good concurrent validity. However, convergent and discriminant validity for both testing batteries has not been thoroughly established.

Convergent validity refers to the extent to which different measures of the same construct are in fact related while discriminant refers to how different measures of different constructs are not related (Campbell & Fiske, 1959). A high convergent validity between two test batteries should result in a high agreement of classification based on both measurement instruments (Cools et al., 2010). However, no recent studies have established convergent and discriminant validity between the KTK and BOT-2 Short Form specifically, or between KTK or BOT-2 Short Form and any other popular motor assessment battery in general. The assessment of convergent and discriminant validity between these two motor competence testing batteries in particular is interesting since both testing batteries have frequently been used in research on motor competence in children (Barnett et al., 2008; Vandorpe et al., 2011a). Therefore, the aim of this study is to assess convergent and discriminant validity between the KTK and BOT-2 Short Form by assessing relationships between KTK Motor Quotient, BOT-2 Short Form standardized score, BOT-2 Short Form gross and BOT-2 Short Form fine motor composite score in a representative sample of 6-12 year old children. In order to measure the level of agreement of classification between both testing batteries at different ends of the motor competence spectrum, this study means to portray the amount and percentage of children that were classified by both testing batteries in the following categories: lower than percentile 5 (p5) and percentile 15 (p15), or higher than percentile 85 (p85) and percentile 95 (p95). It is hypothesized that stronger correlations will be visible between KTK and total BOT-2 Short Form and gross motor composite scores, than between KTK and BOT-2 Short Form fine motor composite scores. Furthermore, since KTK and BOT-2 Short Form aim to identify children with mild to severe motor problems, the agreement of classification between both testing batteries would be highest in the P5 and P15 categories.

Methods

Participants and design

A total of 2485 children (i.e., 1300 boys and 1185 girls) between 6-12 years participated in this study with a cross-sectional design. These children were recruited from 26 primary schools for general education located throughout the Flemish region of Belgium. To obtain a representative sample of the Flemish elementary school population, schools were randomly selected from all 5 Flemish provinces and the Brussels Capital Region and were situated in both rural and city areas. These children completed the BOT-2 Short Form and KTK assessments in a three-month time span in 2007. Written informed consent was obtained from the children's parent(s) or guardian(s). The local

Ethics Committee of the Ghent University Hospital granted permission for this study.

Measures

The BOT-2 Short Form consists of 14 test items from 8 subtests: 1) Fine motor precision: drawing line through crooked paths + folding paper; 2) Fine motor integration: copying a square + copying a star; 3) Manual dexterity: transferring pennies; 4) Bilateral coordination: jumping in place – same side synchronized + tapping feet and fingers – same side synchronized; 5) Balance: walking forward on a line + standing on one leg on a balance beam – eyes open; 6) Upper limb coordination: dropping and catching a ball with both hands + dribbling a ball with alternating hands; 7) Strength: knee push-ups + sit ups; 8) Speed and Agility: jumping on one leg (Bruininks & Bruininks, 2005). The total score for the BOT-2 Short Form was calculated by summing of the numerical scores on the different subtests that were standardized according to normative data of 1520 children living in the US in 2004-2005. To obtain a gross and fine motor composite scores, the sum of the standard numerical scores of their respective items were used. Table 1 shows the subdivision made by a two-factor analysis performed on the point scores for each item of the BOT-2 Short Form to acquire a gross and a fine motor factor (Table 1). The KTK consists of 4 subtests: 1) walking backwards along a balance beam 2) moving sideways on boxes 3) hopping for height on one foot and 4) jumping sideways (Kiphard & Schilling, 1974). From these four subtests, an age- and gender-specific motor quotient (MQ) was calculated based on normative data of 1128 typically developing German children (Kiphard & Schilling, 1974). The KTK and BOT-2 were administered during the same day and all children were given sufficient rest between different subtests.

Data analysis

All data were analysed using SPSS 20 for windows. To assess convergent and discriminant validity between the KTK and BOT-2, Pearson correlations were calculated between KTK Motor Quotient and total BOT-2 Short Form score, BOT-2 Short Form gross motor composite scores (balance + upper limb coordination + strength + speed and agility), BOT-2 Short Form fine motor composite scores (fine motor precision + fine motor integration + manual dexterity) and were used for the total age range (6-12 years) and for three age groups separately (6-7 years, 8-9 years, 10-11 years). Interpretation of the correlation coefficients was as follows: correlation coefficients below .35 are considered weak, between .36 and .67 are considered moderate, between .68 and .89 are considered high and from .90 on are considered very high (Taylor, 1990). In order to determine the agreement in the classification for the amount of children classified in ≤P5, ≤P15, ≥P85 and ≥P95 categories for the KTK Motor

Quotient and BOT-2 Short Form, cross-tabs between both tests were used and Pearson Chi-Square (Chi^2) and Cohen's Kappa (K) values were calculated. According to Landis and Koch (1977) a Cohen's Kappa between .21 and .40 is considered fair, between .41 and .60 moderate, between .61-.80 substantial and Cohen's Kappa bigger than .81 is considered an almost perfect agreement. Significance levels were set at .05.

Table 1: Subtests used in the gross motor and fine motor coordination composite scores for the Bruininks-Oseretsky Test of Motor Proficiency 2 Short Form

BOT-2 Short Form		**KTK**
Gross motor coordination composite score	Fine motor coordination composite score	
Walking forward on a line	Drawing lines through crooked paths	Waling backwards along a balance beam
Standing on one leg on a balance beam (eyes open)	Folding paper	Moving sideways on boxes
Dropping and catching a ball with both hands	Copying a square	Hopping for height on one foot
Dribbling a ball woth alternating hands	Copying a star	Jumping sideways over a slat
Knee push ups		
Sit ups		
Jumping on one leg		
Tapping feet and fingers same side synchronized		
Transferring pennies		

Results

Correlation coefficients and confidence intervals for KTK Motor Quotient and the total BOT-2 Short Form score, gross motor coordination composite score and the fine motor coordination composite score for the total sample and the sample split by age group (6-7, 8-9, 10-11 years) are presented in Table

2. For the total sample, the strongest correlations between KTK and BOT-2 Short Form were found between KTK Motor Quotient and total BOT-2 Short Form score (r = .61, p<0.001) and KTK Motor Quotient and BOT-2 Short Form gross motor composite score (r = .44, p<0.001). A weaker but significant correlation (r = .25, p<0.001) emerged between BOT-2 Short Form fine motor composite score and KTK Motor Quotient. When analysing each age cohort separately, significant correlations (.60 ≥ r ≤ .64, p<0.001) between KTK and total BOT-2 Short Form and gross motor composite scores were also found for each age group separately. For the correlations between BOT-2 Short form fine motor composite scores and KTK Motor Quotient, significant correlation coefficients of .30 ≥ r ≤ .37 (p<0.001) were found for each age group.

Crosstabs showed fair associations and moderate levels of agreement between the KTK and BOT-2 Short Form at the P5 (Chi^2 = 237.5; K = .31, p < 0.001), P15 (Chi^2 = 412.6; K = .42, p < 0.001), P85 (Chi^2 = 265.7; K = 0.33, p < 0.001) and P95 (Chi^2 = 222.4; K = 0.30, p < 0.001). The number of subjects classified in each percentile category by both tests and the percentage of total subjects classified in each group, can be found in tables 3a-d. Thirty-two percent of children classified in the ≤P5 category by the BOT-2 Short Form, were also classified in ≤P5 using the KTK. Thirty-eight percent of children with KTK scores below the fifth percentile were also classified as such by the BOT-2

Short Form. Fifty percent of children classified in the ≤P15 category by the BOT-2 Short Form, were also classified ≤P15 in using the KTK and vice versa. Forty-one percent of children classified in the ≥P85 category by the BOT-2 Short Form, were classified ≥P85 in using the KTK. Forty-eight percent of children with KTK Motor Quotients ≥ P85 were also categorized ≥85 by the BOT-2 Short Form. Thirty-three percent of children classified in the P95 category by the BOT-2 Short Form, were classified as scoring ≥ P95 by the KTK. Thirty-six percent of children scoring ≥ P95 on the KTK were also classified as such by the BOT-2 Short Form. The percentage of total children for whom there was an agreement in classification between the BOT-2 Short Form and KTK was 2.1%, 7.8%, 8.1% and 4.2% for the ≤P5, ≤P15, ≥P85 and ≥P95 categories.

Table 2: Pearson correlation coefficients (r) and (95% confidence intervals) between Bruininks-Oseretsky Test of Motor Proficiency 2 Short Form (BOT-2 SF) standard score, gross and fine motor composite scores and KTK motor quotient

		BOT-2 Short Form		
		Fine Motor Coordination	Gross Motor Coordination	Total score
KTK Motor Quotient	***Total sample (N = 2485)***			
	Motor Quotient (points)	.25 (.22 - .29)	.44 (.41 - .47)	.61 (.58 - .63)
	6-7 years (N = 728)			
	Motor Quotient (points)	.30 (.24 - .37)	.62 (.57 - .66)	.60 (.55 - .64)
	8-9 years (N = 1042)			
	Motor Quotient (points)	.37 (.31 - .42)	.61 (.57 - .65)	.63 (.58 - 67)
	10-11 years (N = 715)			
	Motor Quotient (points)	.31 (.23 - .38)	.61 (.60 - .69)	.64 (.56 - .66)

Note: Gross Motor Composite score BOT-2 Short Form = Balance + Upper Limb Coordination + Strength + Speed and Agility + manual dexterity; Fine Motor Composite score BOT-2 Short Form = Fine Motor Precision + Fine Motor Integration

Table 3: Crosstabs for the amount of children scoring above or below P5, P15, P85 and P95 for Bruininks-Oseretsky Test of Motor Proficiency 2 Short Form (BOT-2 SF) and KTK

		KTK					
		≤P5	% of total cases	>P5	% of total cases	**Total**	% of total cases
BOT-2 SF	≤P5	53	2.1	111	4.5	**164**	6.6
	>P5	86	3.5	2235	89.9	**2321**	93.4
	Total	**139**	**5.6**	**2346**	**94.4**	**2485**	100
		≤P15	% of total cases	>P15	% of total cases	**Total**	% of total cases
BOT-2 SF	≤P15	194	7.8	192	7.7	**386**	15.5
	>P15	196	7.9	1903	76.6	**2099**	84.5
	Total	**390**	**15.7**	**2095**	**84.3**	**2485**	100
		<P85	% of total cases	≥P85	% of total cases	**Total**	% of total cases
BOT-2 SF	<P85	1819	73.2	202	8.1	**2221**	81.3
	≥P85	276	11.1	188	7.6	**264**	18.7
	Total	**2095**	**74.3**	**390**	**25.7**	**2485**	100
		≤P95	% of total	≥P95	% of total	**Total**	% of total cases
BOT-2 SF	<P95	2243	90.2	90	3.6	**2333**	93.8
	≥P95	104	4.2	50	2.0	**154**	6.2
	Total	**2347**	**94.4**	**140**	**5.6**	**2485**	100

Note: Gross Motor Composite score BOT-2 SF = Balance + Upper Limb Coordination + Strength + Speed and Agility + Manual Dexterity; Fine Motor Composite score BOT-2 SF = Fine Motor Precision + Fine Motor Integration

Discussion

The present study aimed to assess convergent and discriminant validity between the KTK and the BOT-2 Short Form in 2485 children aged 6-12 years. Moderately strong positive correlations between KTK Motor Quotient and BOT-

2 total and gross motor composite scores and weak positive correlations between KTK Motor Quotient and BOT-2 Short Form fine motor composite scores were found. Furthermore, levels of agreement between both movement assessment batteries in terms of classification were fair to moderate for P5, P15, P85 and P95.

The moderately strong associations between total scores for the KTK and BOT-2 Short Form show that both tests measure the same construct, being general motor competence, only to a moderate extent. This might be due to the fact that the BOT-2 Short Form involves both gross and fine motor skills, while the KTK mainly involves only gross motor skills. The correlation coefficient between the BOT-2 Short Form and KTK is in accordance with previous research by Smits-Engelsman and colleagues (1998) who found a correlation coefficient of .62 between Movement ABC (Henderson & Sugden, 1992) and KTK. However, Van Waelvelde et al. (2007) mentioned that test scores can only be interpreted in relation to the specific tasks used in the assessment since a correlation of this magnitude between variables does not allow for a complete (100%) explained variance, and thus the variance in one variable is partly explained by other variables. Additionally, Vandorpe et al. (2011a) hypothesized that the difference in physical fitness between boys and girls might explain gender differences in KTK Motor Quotient scores highlighted by their results. Hence, the fact that not only motor competence, but also physical fitness was measured to a different degree in both tests, might also in part explain moderately strong rather than strong correlations between KTK and BOT-2 Short Form.

Proof of convergent and discriminant validity between these two testing batteries is provided to some extent through the moderately strong significant association between KTK and the BOT-2 Short Form gross motor composite scores and the weak significant relationship between KTK and BOT-2 Short Form fine motor composite score. These findings are in accordance with studies by Van Waelvelde and colleagues (2007) on the relationship between Movement ABC (Henderson & Sugden, 1992) and Peabody Developmental Motor Scales (Folio & Fewell, 1974) and Cools et al. (2010) on the relationship between MOT 4-6 (Zimmer & Volkamer, 1984) and the M-ABC (Henderson & Sugden, 1992), where higher correlation coefficients were found between gross or fine motor composite scores of each battery, than between gross motor composite scores of one and fine motor composite scores of the other.

In the current study, convergent and discriminant validity was assessed in three age cohorts (6-7 years, 8-9 years, 10-11 years) separately. Moderate to strong significant correlations between KTK Motor Quotient and total and gross motor composite scores for the BOT-2 Short Form were found in all age cohorts. Hence, in each age group separately, convergent validity was better and discriminant validity was worse than in the total sample. These results demonstrate that when using the KTK and BOT-2 Short Form as a measure of gross motor competence in large test samples, the interpretation of results within age-groups with smaller age ranges might be more valuable than interpreting results in a sample with a wide age range.

The levels of agreement between both movement assessment batteries in terms of classification were fair to moderate for 5P, P15, P85 and P95. However, for P5, P85 and P95 the level of agreement was lower (K = .31, K = .33, K = .30 respectively), than for P15 (K = .42). This means that agreement of classification (and convergent validity) for both testing batteries is moderate when KTK and BOT-2 Short Form are used to discriminate children with a relatively poor motor competence from those with average to good motor competence but only fair when trying to classify children with relatively high or very poor motor competence. These relatively low levels of agreement in classification might be due to different constructs being measured to some extent by both batteries. The difference in normative data being used (KTK: 1128 German children in 1974; BOT-2 Short-Form 1520 American children 2004-2005) to calculate standardized scores for both testing batteries might also explain the relatively poor levels of agreement between both batteries.

However, we chose to calculate standardized scores based on these normative values rather than to calculate standardized values because this method allows for an easy comparison with other studies.

Because of the low levels of agreement between KTK and BOT-2 Short Form reported in this study, practitioners/clinicians should be mindful of potential wrongful categorisation when using either the KTK or BOT-2 Short Form for the detection of severe motor problems. Indeed, the results of this study showed that (only) 50% of the children that were categorized below the 15th percentile by the KTK were likewise categorized by the BOT-2 Short form and vice versa. Since both testing batteries were designed with the aim of identifying children with mild to severe motor problems (Kiphard & Schilling, 1974; Bruininks & Bruininks, 2005; Deitz et al., 2007), these findings are not surprising. However, because of the only fair to moderate agreement between both testing batteries, researchers should bear in mind the potential wrongful categorization of individuals when using the BOT-2 Short Form or KTK alone to assess motor competence. Therefore, it might be better to use more than one assessment battery when measuring motor competence.

The main strength of this study is firstly its large sample size. Comparable studies (Smits-Engelsman et al., 1998, Van Waelvelde et al., 2007; Cools et al., 2010) had a sample size of 31, 48 and 208 subjects respectively, while the present study has a sample size of 2485 children, representative for the Flemish elementary school population. A second strength of this study is assessing children in a six-year age band (6-12 years). In this age cohort, the development of motor competence contributes highly to the successful engagement in everyday physical activity and organized sports (Barnett et al., 2008). Therefore, using reliable and valid motor competence assessment tools in this particular age group is paramount towards the early detection of poor (or outstanding) motor competence. A limitation to the study is the use of point scores for the gross and fine motor constructs of the BOT-2 Short Form because the absence of standardized values for the BOT-2 Short Form gross and fine motor composite scores.

In conclusion, the aim of this study was to establish convergent and discriminant validity between BOT-2 Short Form and KTK. Moderately high correlations between KTK Motor Quotient and the total and gross motor composite score of the BOT-2, weak correlations between KTK and BOT-2 Short Form fine motor composite score and fair to moderate levels of agreement in the classification of children in motor competence groups based on percentile scores on both tests show reasonable proof of convergent and discriminant validity. However, future research should focus on assessing convergent and discriminant validity between BOT-2 Short Form, KTK and other gross motor competence testing batteries, preferably with well-established gross and fine motor subscales.

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CHAPTER II: MOTOR COMPETENCE FROM A LONGITUDINAL PERSPECTIVE

STUDY 2:

Can the KTK provide support for a plateau phase in motor competence development in a two-year longitudinal study?

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Abstract

The aim of this study was to use a quasi-longitudinal design to investigate changes in motor competence in children aged 6.0-11.9 years at baseline testing using the KTK. A total of 746 children from six age cohorts (6, 7, 8, 9, 10, 11 years) participated in this two-year longitudinal assessment. A repeated measures MANOVA was used to assess changes in four KTK subtests. The results in this study show a significant agegroup*time interaction effect ($F = 12.116$; $p<0.001$). Also, significant performance improvements in motor competence over two years we revealed for all except the 11 year old age cohort (6 years: $F = 211.622$, $P<0.001$; 7 years: $F = 225.186$, $P<0.001$; 8 years: $F = 176.885$, $P<0.001$; 9 years: $F = 119.384$, $P<0.001$; 10 years: $F =5.262$, $P=0.002$; 11 years: $F = 2.400$, $P=0.075$). Where significant changes in motor competence were found, lower effect sizes were found in the older than in the younger age cohorts, suggesting a more significant improvement in motor competence in the youngest age groups (6 years: Effect size = .87; 7 years: Effect size = .86; 8 years: Effect size = .81; 9 years: Effect size = .69; 10 years: Effect size = .39). These results may provide proof of a rapid performance improvement before 11 years and a slower performance improvement, or even a plateau phase for motor competence development from the age of 11 years on.

Introduction

The development of motor skills starts from birth where infants try to engage in purposeful actions involving large muscle groups of the body (Cratty, 1986). Between age three to five, a child starts to build upon these basic movement patterns and shows more consistency in movement patterns (Rose-Jacobs, 1983). Also between three to five years, children expand their array of skills and start rapidly developing different stages of the so called 'fundamental movement skills', such as jumping, hopping, balancing, skipping and throwing. In the final years of childhood motor development (5-12 years), a rapid development of specific movement qualities such as dynamic balance, agility, speed, strength and power is observed as children start competing in game-like physical activity with peers (Cratty, 1986). Inter-individual discrepancies in the development of these qualities and in the participation in (un)structured physical activity results in great variations in motor competence observed within a general population (Wrotniak et al., 2006)

Many testing batteries have been devised to accurately measure this great variation in motor competence in children. For an elaborate review, please consult Cools et al. (2008). One of these tools is the KTK (Kiphard and Schilling, 1974; 2007). The KTK was originally developed to identify mild to severe movement difficulties in 4-15 year old children but more recently, it has also been used talent detection and identification purposes (Vandorpe et al., 2011; Vandendriessche et al., 2012; Fransen et al., 2012).

In 1986, Borms mentioned that studies investigating ‘a golden age’ at which a child can easily acquire new movement patterns (9-12 years) is abundant. However, more recent research on the development of motor competence in general populations of children is scarce. Cross-sectional research by Vandorpe and colleagues (2011) reported significant differences in KTK (Kiphard and Schilling, 1974) scores between age-groups in 6-12 year old children. This study showed higher scores on all KTK-subtests in subsequent age groups in favour of the oldest age groups. Unfortunately, it was outside of the scope of that particular study to investigate the magnitude of this age group effect. In 2001, Largo and colleagues showed centile curves for timed performance on nine motor competence tests based on cross-sectional data of 662 children between 5-18 years. They suggested a non-linear improvement in timed performance on all tests throughout the pre-pubertal period, often resulting in a performance plateau. This research group also suggested that the overall rate of performance improvement and the age at which performance on a certain motor skill reaches a plateau is related to the complexity of that motor skill. Repetitive motor skill levelled off between 12-15 years, while alternating movements levelled off later on (around 18 years).

Longitudinal research by Ahnert and colleagues (2009) assessed developmental changes and stability of motor competence from early childhood (4 years) into young adulthood (23 years) using the Motor Test for 4-6 year olds (MOT 4-6, Zimmer and Volkamer, 1984) and the KTK (Kiphard and Schilling, 1974). This study had measurements at 4, 5, 6, 8, 10, 12 and 23 years and showed that scores on both testing batteries improved with age. Furthermore, from 12 years on, a significant sex-effect on KTK scores was observed: female participant no longer improved their scores over time. This confirms the hypotheses based on cross-sectional research on the existence of a period of rapid progress in motor skill development between 4 and 12 years, followed by a slower progression later on (Cratty 1986; Singer & Bös, 1994).

Therefore, specific programs with the aim of improving motor competence during these ‘critical windows’ could be paramount in the overall athletic development of children. Moreover, understanding motor competence development during childhood might help to pinpoint talent identification and detection opportunities and optimize talent development. The abovementioned research however does not provide an in depth (year-by-year) longitudinal analysis of motor competence specifically using an easy to administer assessment tool. Therefore, the current study used a reliable and valid motor competence assessment instrument in a quasi-longitudinal design to assess short-term changes (two years) in motor competence in six age cohorts (6, 7, 8, 9, 10, 11 years at baseline testing). Based on previous research on the development of motor competence, we expected an improvement in motor competence in every age cohort over the two-year time span of this study. However, we hypothesized that improvements would be greater in the youngest than in the oldest age cohorts, suggesting a potential slower improvement or even plateau phase in motor competence development during late childhood (11-13 years).

Methods

Participants and design

At baseline measurement, motor competence was assessed for 2613 children aged 6-12 years. Finally, 746 children from six age cohorts at (6.00-6.99 years: n = 136; 62 boys and 73 girls, 7.00-7.99 years: n = 150; 82 boys and 62 girls, 8.00-8.99 years: n = 169; 87 boys and 83 girls, 9.00-9.99 years: n = 223; 110 boys and 113 girls, 10.00-10.99 years: n = 37; 24 boys and 13 girls and 11.00-11.99 years: n = 31; 19 boys and 13 girls) participated in this quasi-longitudinal cohort study between 2007 and 2009. A total of 1867 children were not retested on one or more KTK subtests at baseline + 2 years due to absence at school on the day of testing, a move to another school or a voluntary drop out of the study. This group is referred to as the reference group from here on. Descriptive statistics for the reference and test samples in each age cohort are reported in Table 1. The subjects in this study were recruited from twenty-six Flemish primary schools for general education. To obtain a representative sample of the Flemish elementary school population, schools were randomly selected from all school systems in five Flemish provinces and the Brussels Capital Region and were situated in both rural and city areas. Table 1: Descriptive statistics (mean + standard deviation) for the test and reference sample for each age cohort, F values show no difference in Motor Quotient between Test and Reference sample.

Table 1: Descriptive statistics (mean + standard deviation) for the test and reference sample for each age cohort, F values show no difference in Motor Quotient between Test and Reference sample

		Test Sample (N=746)					Reference sample (N=1866)				F-value	significance
		Age (years)	Height (cm)	Weight (kg)	r Quotient (points)		Age (years)	Height (cm)	Weight (kg)	r Quotient (points)	Motor Quotient	
6 years	*N* = 136	6.6±0.3	119.9±5.3	22.5±3.1	94.4±12.8	*N* = 180	6.6±0.3	119.9±5.8	23.1±4.2	94.6±14.0	0.000	0.985
7 years	*N* = 150	7.5±0.3	126.3±5.4	25.7±3.8	99.4±15.3	*N* = 304	7.5±0.3	126.8±5.8	26.5±4.9	97.6±14.1	1.820	0.178
8 years	*N* = 169	8.5±0.3	132.5±5.7	29.0±6.0	97.4±15.2	*N* = 339	8.5±0.3	132.5±5.6	29.9±6.0	96.7±14.7	0.563	0.453
9 years	*N* = 239	9.5±0.3	136.6±6.2	31.6±6.0	94.2±13.9	*N* = 372	9.5±0.3	137.4±6.2	32.4±6.5	94.1±16.0	0.001	0.970
10 years	*N* = 37	10.4±0.2	142.3±7.7	35.4±6.3	89.6±18.2	*N* = 337	10.5±0.3	142.6±6.3	36.1±7.4	92.6±13.5	0.821	0.366
11 years	*N* = 31	11.5±0.2	150.6±7.3	42.9±9.0	93.4±14.4	*N* = 334	11.5±0.3	148,6±6.9	40.7±8.8	97.8±16.8	0.239	0.239

Note: MQ = Standardised Motor Quotient derived from age and gender specific norm values for the KTK in 1128 typically developing children (Kiphard and Schilling, 1974)

Measurements

Four subtests of the KTK (Kiphard and Schilling, 1974) were administered to evaluate two-year longitudinal changes in motor competence: 1) walking backwards along a balance beam 2) moving sideways on boxes 3) hopping for height on one foot and 4) jumping sideways. For an elaborate description of these tests, please consult Kiphard and Schilling (1974).

Data analysis

To analyse two-year longitudinal changes in KTK subtest scores, repeated measures MANOVA with KTK subtests as dependent variables, age group as a between-subjects factor and time as a within subjects factor, was used to evaluate longitudinal changes in motor competence in 6 age cohorts. Effect sizes with cut-off scores of 0.01, 0.06 and 0.14 were considered small, moderate and strong respectively and were used to estimate the magnitude of differences between baseline and baseline + 2 years assessments (Cohen, 1988). We chose not to use gender as a fixed factor in these analyses since a preliminary analysis showed a time*gender interaction effect only in the 6 and 10 year old cohorts. Significance levels were set at 0.05

Results

Means ± standard deviations for KTK subtests at baseline and baseline + 2 years for 6 age cohorts are shown in Table 2. Repeated Measures MANOVA revealed a significant agegroup*time interaction ($F = 12.116$; $p<0.001$) effect on KTK subtest scores. A significant ($P<0.001$) univariate interaction effect was found for all KTK subtests (Jumping Sideways: F = 41.175; Moving Sideways: F = 19.592; Hopping For Height: F = 24.572; Balancing Backwards: F = 15.101)

A significant within-subjects multivariate effect of time (baseline, baseline + 2 years) for the cohorts aged 6-11 years at baseline (6 years: F = 211.622, P<0.001, Effect size = .87; 7 years: F = 225.186, P<0.001, Effect size = .86; 8 years: F = 176.885, P<0.001, Effect size = .81; 9 years: F = 119.384, P<0.001, Effect size = .69; 10 years: F =5.262, P=0.002, Effect size = .39). In the eleven-year-old age cohort, a trend towards a significant effect of time was found (F = 2.400, P=0.075, Effect size = .26). At a univariate level, a within-subject effect of time on all KTK subtests was found for 6-10 year old children. KTK scores for all cohorts improved over the two-year time span. No significant effects of time were found on any of the KTK subtests in the 11-year old group (Figure 1).

Table 2: Means ± standard deviations for KTK subtests raw scores at baseline and baseline + 2 years for 6 age cohorts

	Baseline	Baseline +2 years	F Time	Effect size	*P*
Jumping sideways					
6 years	35.9±9.0	55.7±10.4	644.210	.83	<0.001
7 years	44.5±10.9	62.4±11.1	411.995	.73	<0.001
8 years	50.9±11.1	65.2±12.0	328.485	.66	<0.001
9 years	56.9±10.9	69.1±11.7	266.202	.55	<0.001
10 years	58.5±12.7	63.7±12.4	4.348	.11	0.044
11 years	64.4±9.6	60.1±11.9	3.083	.09	0.090
Moving sideways					
6 years	29.3±5.2	42.6±6.9	499.542	.79	<0.001
7 years	33.3±5.1	45.8±7.1	694.911	.82	<0.001
8 years	36.5±5.6	47.6±7.7	496.205	.75	<0.001
9 years	39.5±6.2	49.8±7.8	397.921	.64	<0.001
10 years	40.6±6.1	47.2±8.3	18.623	.34	<0.001
11 years	43.7±7.8	44.8±7.0	0.430	.01	0.517
Hopping for height					
6 years	31.9±11.2	56.3±14.0	390.534	.74	<0.001
7 years	41.2±12.9	60.9±15.3	422.238	.74	<0.001
8 years	48.7±13.1	66.3±15.1	434.921	.72	<0.001
9 years	55.0±12.4	69.1±17.0	240.796	.52	<0.001
10 years	59.4±14.1	70.7±16.1	15.039	.30	<0.001
11 years	62.9±12.5	61.7±14.4	0.125	.00	0.726
Balance beam					
6 years	24.8±11.2	41.6±14.0	219.678	.62	<0.001
7 years	33.8±13.3	45.6±13.1	110.135	.43	<0.001
8 years	38.5±13.8	47.1±14.2	70.372	.30	<0.001
9 years	41.7±12.7	47.6±14.0	36.779	.14	<0.001
10 years	42.3±15.9	48.6±13.4	6.683	.16	0.014
11 years	45.5±14.7	44.4±14.4	0.098	.00	0.757

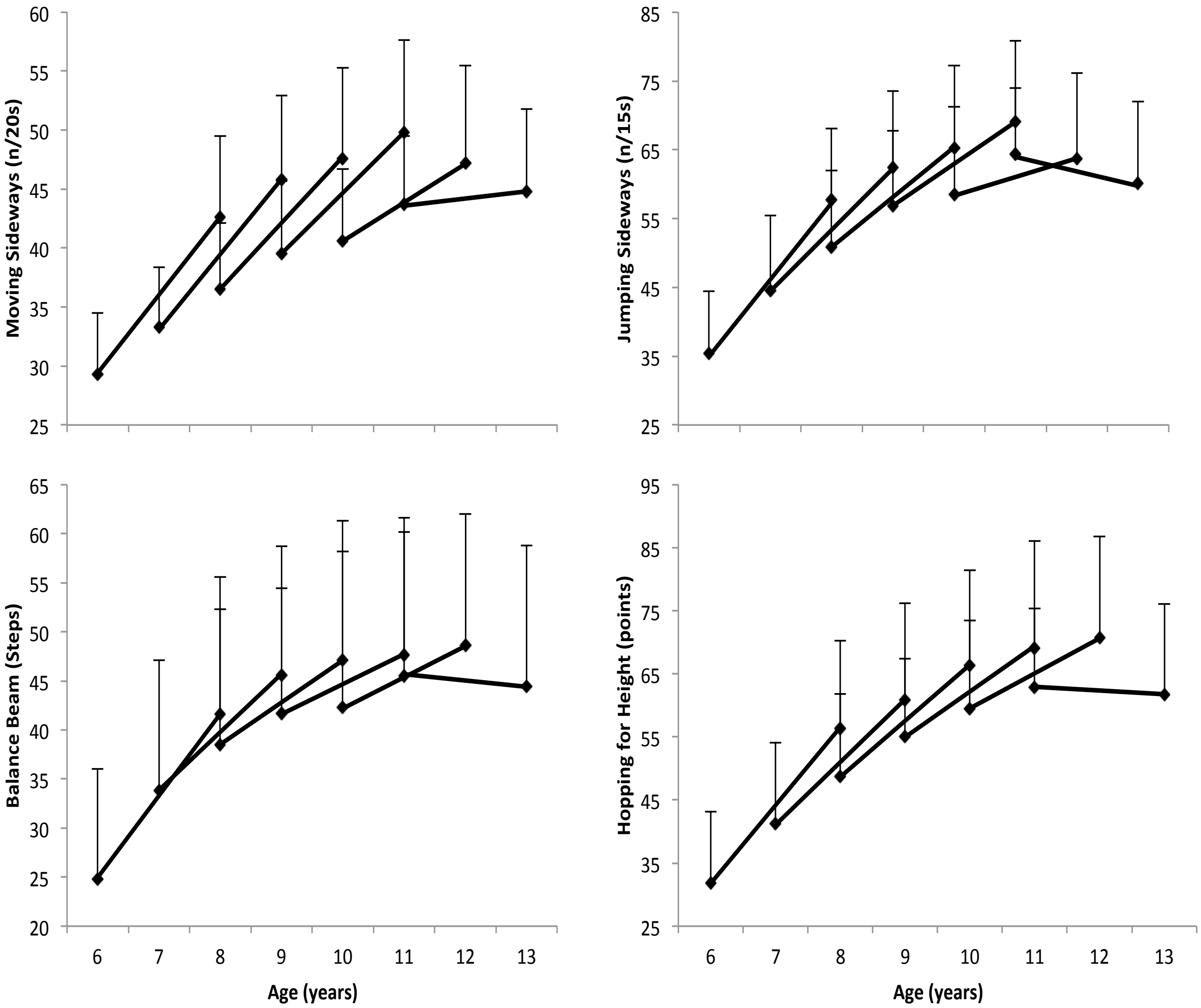

Figure 1: Changes over two years in scores on KörperkoördinationsTest fûr Kinder Balance Beam, Hopping for Height, Moving Sideways and Jumping Sideways raw scores in 6 age cohorts (6, 7, 8, 9, 10 and 11 years)

Discussion

The results in this study show significant performance improvements in scores on tests measuring gross motor competence and balance over the two-year span. A significant multivariate agegroup*time effect was found on KTK subtest scores. A significant multivariate main effect of time was found for all KTK measures in the 6-10 year old cohorts. No significant time effect was found for any of the subtests in the 11 year old age group. Furthermore, however effect sizes were strong based on guidelines by Cohen (1988), lower effect sizes were found in the older than in the younger age cohorts, suggesting a more significant improvement in motor competence in the youngest age groups. The results in this study confirm our hypothesis that performance improvements on KTK subtests would be apparent in the youngest age groups, and would be less apparent or even absent in the oldest age group(s) and in accordance with Borms et al. (1986) who mentions that there is a sensitive period for motor competence development between 9-12 years. Largo et al. (2001) elaborated on these findings by suggesting that repetitive (continuous) motor skill level off between 12-15 years, while alternating (serial) movements reach a plateau later on. The KTK jumping sideways, moving sideways and balancing backwards tests can be classified as repetitive skills according to a commonly used one-dimensional classification system while hopping for height would be classified more as a serial skill (Magill, 2007). However, in the current research, KTK scores in general rather than scores on specific subtests showed a smaller increase in scores and even seemed to plateau around 12 years.

The first explanation for the existence of a possible performance plateau for motor competence can be found in the neurophysiological view on the development of motor competence. Fietzek et al. (2000) investigated the duration of central motor conduction in 72 children and 40 adults while performing different motor tasks. This research group found a rapid decrease in central motor conduction times in the first decade and related this to the maturation of the central nervous system. For a comprehensive review on the neurophysiological concept of brain maturation, please consult Webb et al. (2001). Therefore, it is possible that the peak in motor competence development before the age of 10 years is due to the ongoing process of central nervous system maturation. For a second explanation for the absence of improvements in motor competence tasks in the oldest age cohorts, we refer to research on anthropometrical changes during puberty. According to Visser et al. (1998), metrical changes related to pubertal growth spurts are likely to negatively affect performance on motor coordination tasks. These changes negatively affect body movements of inertia, and therefore disrupt movement biomechanics (Jensen, 1981; Mirwald et al., 2002), results in 'awkward and clumsy movement' in adolescents. Visser et al. (1998) found a significant relationship between the rate of growth and motor competence development in 30 children. Philippaerts et al. (2006) also revealed that most EUROFIT (Council of Europe, 1988) fitness tests reached their peak velocity around the moment of peak height velocity and declined thereafter. Although the age range in the current sample was too young for all subjects to reach peak height velocity during the study, we believe that rapidly changing body dimensions in this age group might be a contributing factor to a plateau in motor competence development.

Although in the current research, maturation was not assessed and neither were any neurophysiological variables, we do believe that understanding changes in gross motor competence during childhood has important implications for the development of motor competence in all ranges of the athletic development spectrum. This study provides some evidence for a relatively strong performance improvement in gross motor competence before the age of 12 years, and a slower performance improvement or even a 'performance plateau' from 11-12 years on. Although the span of this study did not cover the adolescent years and therefore we can not conclude on motor competence development during this period, we believe that talent development programs seeking to develop talented individuals with the prospects of athletic careers as well as specialised training programs for children with low motor competence, should emphasize motor competence development at an early age, preferably before puberty.

In conclusion, the KTK reveals faster improvements in motor competence between 6-11 years and a slower improvement from 11 years on. This shows that developing motor competence before the age of 10-11 years might be crucial to assure adequate motor competence in children from a general population and could provide valuable information on motor competence development for talent development programs and interventions aimed at improving motor competence in children with motor development problems. The strengths for this study are its large sample size, its representativeness for the general Flemish population between 6-12 years and the ability to include longitudinal measurements of motor competence using the KTK as a measure for gross motor competence specifically. This study also showed some weaknesses. It reported a large drop out rate between baseline and baseline + 2 years measurements. However, table 1 showed that this drop out was not per se selective for the whole test sample on the basis of motor competence. Furthermore, the relatively small sample size compared to the other cohorts in the two oldest age groups is a shortcoming. However, descriptive statistics show similar standard deviations in these and other cohorts. It should also be mentioned that, although no sex*time differences were found in the 11 year old age cohort in this study, the difference in age at peak height velocity in boys (13.5 years) and girls (11.5 years) (Abassi, 1998) and consequently the relatively unequal distribution in the 11 year old group could possibly affect the results.

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STUDY 3:

Changes in physical fitness and sports participation among children with different levels of motor competence: a two-year longitudinal study.

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Abstract

The goal of this study was to investigate differences in physical fitness and sports participation over two years in children with relatively high, average and low motor competence. Physical fitness and motor competence of 501 children between 6-10 years were measured at baseline and baseline+2 years. The sample compromised 2 age cohorts: 6.00-7.99 and 8.00-9.99 years. An age and sex-specific motor quotient at baseline testing was used to subdivide these children into low (MQ<P33), average (P33≤MQ<P66) and high (MQ≥P66) motor competence groups. Measures of sports participation were obtained through a physical activity questionnaire in 278 of the same children. Repeated Measures MANCOVA and two separate ANOVAs were used to analyse differences in changes in physical fitness and measures of sports participation respectively. Children with high motor competence scored better on physical fitness tests and participated in sports more often. Since physical fitness levels between groups changed similarly over time, low motor competent children might be at risk of being less physically fit throughout their life. Furthermore, since low motor competent children participate less in sports, they have fewer opportunities of developing motor abilities and physical fitness and this may further prevent them from catching up with their peers with an average or high motor competence.

Introduction

A minimal level of motor competence, ranging from fine coordination to gross motor coordination and balance skills, is necessary in order to participate in daily physical activities typical of young children. A typically developing child should easily master locomotion skills like walking, running, hopping and climbing and object control skills like catching and throwing around the age of elementary school entry (Hands & Larkin, 2002; Haga, 2008), usually at 6 years in Belgium. However, while some children execute a whole range of motor tasks with ease, others experience considerable difficulties coordinating and controlling their body movements. The latter children are often diagnosed with Developmental Coordination Disorder (DCD). DCD affects 5-6% of the normal school population (Blank et al., 2012) and is characterized by motor problems negatively interfering with everyday sports and leisure activities (Polatajko & Cantin, 2006; Summers et al., 2008).

Physical fitness is the capacity to perform physical activity (Ortega et al., 2008) and can be divided into health related and performance related fitness. Health related fitness consists of physical and physiological components that directly affect health (Powell et al., 1998) such as cardiorespiratory fitness, muscular strength, muscular endurance and flexibility (Howley, 2001) and is of particular interest to this study. It has been hypothesized that children with a low motor competence are not sufficiently physically active, resulting in lower physical fitness levels compared to children with high motor competence (Hands, 2008; Haga, 2009; Cairney et al., 2011). It is possible that some children enhance their physical fitness through basic motor actions such as running, jumping, climbing etc. that are needed to engage in physical activity (Saakslahti et al., 1999; Cantell et al., 2008). Therefore, the development of physical fitness in children who face difficulties in executing these motor tasks is problematic. A combination of poor physical fitness and poor motor competence can contribute to early fatigue (O'Beirne et al., 1994; Hands & Larkin, 2002) and thereby limit opportunities to develop motor competence through playground play, after school sport and backyard activities. Cross sectional research has established a positive relationship between motor competence and health-related physical fitness in 9-10 year old children (Haga, 2008), 6th grade primary school children (Vedul-Kjelsas et al., 2011) and adolescents (Stodden et al., 2009) and revealed below average performances on tests of flexibility, cardiovascular endurance, speed and agility and strength (Hands & Larkin, 2006; Cairney et al., 2007; Schott et al., 2007; Cantell et al., 2008).

Since one cannot presume that children with motor problems would simply 'grow out' of their coordination difficulties with age (Cantell et al., 2003), longitudinal research on differences between the development of (health-related) physical fitness in low and high motor competent children is paramount. Cairney et al. (2011) revealed a performance difference between children with DCD and typically developing children on the Léger 20m shuttle run test in a sample of 2083 grade four (mean age 9 years, 11 months) children. When observing the effect of motor competence on a set of physical fitness variables in 168 5-7 year old boys and girls over a five-year period, Hands (2008) identified that children with an initially low motor competence (n=19) had lower scores on standing broad jump, needed more time to execute a 50m run, had reduced balance (times), shorter distance throws and lower cardiovascular endurance at every testing occasion than a high motor competence group (n=19). Haga (2009) later confirmed these findings in a sample of 67 children. In both of these studies, between-group differences remained similar over time suggesting that children who possess poor motor competence or a low fitness level at a young age, are unlikely to catch up with their peers with age (Hands, 2008; Haga, 2009).

In 2001, Okely (2001) and colleagues identified physical activity as an important mediator in the relationship between motor competence and physical fitness over time. Later on, this was supported by Cairney et al. (2006; 2011) and Hands (2008), who expressed their concern that children with low motor competence may continue to show decreased participation in physical activity, possibly resulting in a further decrease of physical fitness levels. Moreover, a two-year longitudinal study of 2083 Canadian grade four children showed that the activity deficit between children with DCD and typically developing children was different for boys and girls (Cairney et al., 2010). The activity deficit in girls between groups is serious but stable, while the deficit seems to diminish over time in boys. Haga (2009) found that children with a higher motor competence choose to participate in a more varied range of physical activities, giving them the opportunity for a variety of movement experiences which might in turn result in greater amounts and intensity of physical activity (Stodden et al., 2009) because of a lower energy expenditure and less fatigue for a certain activity (Wrotniak et al., 2006).

In conclusion, the indications for a link between motor competence and physical fitness are abundant. However, longitudinal studies on this association had relatively small sample sizes (Hands, 2008; Haga, 2009), assessed only one measure of physical fitness (Cairney et al., 2011) or did not include a measure of physical activity (e.g. total time spent in physical activity, sports participation) (Hands, 2008; Haga, 2009; Cairney et al., 2011). Furthermore, most previous research on the effect of motor competence on physical fitness has focused on comparing children with and without motor problems. Research has not yet focused on comparing children with a relatively low, moderate high motor competence from a general population of 6-10 year old children although identifying children at risk of developing low motor competence and physical fitness at a young age within this population is important. Therefore, the main goal of this study was to investigate changes in physical fitness and sports participation between relatively high, moderate and low motor competent children from an elementary school population, aged 6-10 years at baseline. It was hypothesized that highly competent children would outperform their peers with a relatively low motor competence at all times and that these differences would remain similar over time. Also, children with high motor competence would spend more hours participating in sports per week than their peers with low motor competence and these differences would increase in time.

Methods

Participants and design

In the first year of the study, 2024 children (1036 boys and 988 girls) between 6-10 years (= age at baseline) were tested for strength, flexibility, speed, agility and motor competence. A subsample that consisted of 501 children (268 boys and 233 girls) was tested both at baseline and baseline +2 years. Hence, the data of 1324 children were not gathered at baseline +2 years due to absence at school on the day of testing, a move to another school or a voluntary drop out of the study. Significant differences in the descriptive measures existed between test and drop out groups (Table 2: F= 12.112; *P*<0.001), however the differences were not systematically in favour of either group. For the analysis on the effect of motor competence on physical activity, only responders of the physical activity questionnaire (FPAQ, 30, see further in the text) were included. From the subsample of 501 children, 278 completed this questionnaire on both occasions. Cantell et al. (1994) suggest that children with relatively severe movement difficulties continue to experience persistent movement related difficulties into adolescence and possibly adulthood, and that their difficulties may even increase with age. Although the current study does not span into adolescence or adulthood, it is possible that age related effects of motor competence on physical fitness and sports participation might also emerge in this study. Therefore, the test sample was split up into two age cohorts (Age Cohort 1: 6.00-7.99 years and Age Cohort 2: 8.00-9.99 years).

The children in this longitudinal study were recruited from nine sports clubs involved in the SPORTAKUS-project, as well as twenty-six primary schools for general education located in the Flemish part of Belgium, involved in the 'Flemish Sports Compass', a government funded screening and orientation tool for youth sports (Vandorpe et al., 2011). The SPORTAKUS project is funded by a local non-profit organization and aims to collect data on physical fitness, motor competence and sports participation in children living in the western region of Flanders. Written informed consent was obtained from the children's parent(s) or guardian(s). The local Ethics Committee of the Ghent University Hospital granted permission for this study.

Measurements

Physical fitness levels were assessed through the use of items from the Bruininks-Oseretsky Test of Motor Proficiency (BOT2; Bruininks & Bruininks, 2005) and the Eurofit Physical Fitness Test Battery (EUROFIT; Council of Europe, 1988). Test items in this test battery were the 1) BOT2 sit-ups- and knee push-ups test to measure muscular strength and endurance, 2) the EUROFIT handgrip strength to measure maximal strength, 3) the EUROFIT standing broad jump to measure explosive strength, 4) the EUROFIT sit and reach test to measure hamstring and lower back flexibility, 5) the EUROFIT 10x5m shuttle run test to assess speed and agility and 6) the EUROFIT 20m endurance shuttle run test as a field test to assess cardiovascular endurance. Test-retest reliability for the BOT2 sit-ups and knee push-ups test subtests was reported to be 0.86 (4-7 years) and 0.87 (8-12 years), respectively. The EUROFIT testing battery is a commonly used testing battery for overall motor performance. Reliability of the EUROFIT subtests is guaranteed by the EUROFIT test manual (Council of

Europe, 1988) and thoroughly established in previous studies (Kemper & Van Mechelen, 1996; Simons, 1999)

Since motor competence involves measures of gross motor coordination (Henderson & Sugden, 1992), this study used the KTK (Kiphard and Schilling, 1974) to determine levels of motor competence in the test sample. The KTK test battery consists of four subtests: 1) walking backwards along a balance beam, 2) moving sideways on boxes, 3) hopping for height on one foot, and 4) jumping sideways. Sex and age-specific scores for motor competence were obtained by transforming the raw data of four KTK subtests into a motor quotient (MQ). For an elaborate description, including validity and reliability of the abovementioned tests, consult Vandorpe et al (2011). The MQ-scores from the entire sample (n = 2024) in this study were used to create three MQ-groups (high, average and low) using the 33rd and 66th percentile of the respective age (6, 7, 8 and 9 years) and sex (boys and girls) as cut-off points (Table 1). A team of trained supervisors scored each test. All tests were performed with bare feet in an indoor sports infrastructure and were assessed within the same three-month time span each year (i.e., September-November).

Table 1: Age and sex specific MQ (points) cut-off scores for used to divide children in an MQLOW, MQAV and MQHI group.

		Boys				Girls		
Age at baseline		MQLOW	MQAV	MQHI		MQLOW	MQAV	MQHI
6 years	*N*=144	MQ<91	91≤MQ<102	MQ≥102	*N*=171	MQ<86	86≤MQ<97	MQ≥97
7 years	*N*=248	MQ<95	95≤MQ<107	MQ≥107	*N*=206	MQ<89	89≤MQ<102	MQ≥102
8 years	*N*=262	MQ<90	90≤MQ<101	MQ≥101	*N*=248	MQ<93	93≤MQ<105	MQ≥105
9 years	*N*=295	MQ<92	92≤MQ<104	MQ≥104	*N*=299	MQ<84	93≤MQ<99	MQ≥99

Note: MQLOW = relatively low motor competence, MQAV = relatively average motor competence and MQHI = relatively high motor competence

Table 2: Descriptive statistics (Mean ± SD) for the drop out and test samples at baseline testing

	Test sample	Drop out	*F*-value
	Mean±SD	Mean±SD	Group
	N = 501	*N* = 908	
Age (years)	8.2±1.2	8.4±1.0	3.860
Body Weight (kg)	28.0±6.2	29.2±6.5	11.475**
Body Height (cm)	130.2±8.6	131.4±8.1	6.391*
Sit and reach (cm)	21.0±5.5	20.1±6.0	6.849**
Sit-ups (n/30s)	17.8±7.3	17.2±8.0	2.329
Knee push-ups (n/30s)	21.9±5.5	21.1±6.7	5.258*
Hand grip (kg)	16.1±4.3	16.3±3.9	1.271
Standing broad jump (cm)	119.5±20.3	123.8±19.9	15.461**
10x5m shuttle run (s)	23.8±2.2	23.4±2.1	11.838**
Endurance shuttle run (min)	4.0±2.0	4.9±2.3	51.710**
MQ (points)	95.0±14.3	95.4±14.7	0.867

*Note: * = p<0.05; ** = p<0.01*

The nature of the activities in which the children participated (i.e., type of sport or physical activity, club membership) and the total time per week spent in organized physical activity (i.e., in a sports club) during the years in which the testing took place were obtained through self-reported physical activity assessment using the Flemish Physical Activity Computerized Questionnaire (Philippaerts et al., 2005). Two variables were computed as measures of sports participation: 1) the total amount of sports participation (recreational or competitive) relative to the amount of months one participates in these activities (i.e., 'total time'), and 2) the total time spent in recreational (not participating in official competition) or competitive (participating in official competition) sports at a club level (i.e., 'club'). Due to the relatively young age of some of the participants, the questionnaire was completed with the help of their parents or guardians. Verstraete (2006) showed that in young children, the help of an adult is desired to obtain sufficient validity and reliability.

Data analysis

All data were analysed using SPSS 19.0. Age cohorts were analysed separately using the 'split file' command in SPSS. A preliminary analysis (t-test) showed that within age cohorts, physical fitness scores were significantly affected by age; therefore age was considered a covariate in the following analyses. When comparing changes in physical fitness measures between

MQLOW (Low Motor Quotient), MQAV (Average Motor Quotient) and MQHI (High Motor Quotient) groups, a 2 (time) * 3 (motor competence) * 2 (sex) repeated measures MANCOVA (age as a covariate) was used. The dependent variables in this analysis were the physical fitness measures (sit and reach, knee push-ups, sit-ups, hand grip strength, standing broad jump, 10x5m shuttle run and endurance shuttle run). To investigate the difference in sports participation between MQ groups, two 2 (time) * 3 (motor competence) * 2 (sex) repeated measures ANOVAs were used with the total amount of sports participation (recreational or competitive) relative to the amount of months one participates in these activities ('total time') and the total time spent in recreational or competitive sports at a club level ('club') as dependent variables. Sex was included as a fixed factor since sex differences in changes in the effect of motor competence on participation have been established (Cairney et al., 2010). Multiple comparisons with a Bonferroni correction were used for post-hoc analysis in case of a significant effect of MQ group. The level of significance was set at 0.05.

Results

The results (mean±SDs, univariate F-values and covariate F-values) of the Repeated Measures Analysis are reported in table 3 for boys and girls in both initial age cohorts (6-8 years and 8-10 years). The Repeated Measures

MANCOVA did not reveal significant multivariate time*MQgroup*sex interaction effect. A multivariate time*MQgroup interaction effect was found in the 8-10 year old children ($F=3.067$, $P<0.001$). Furthermore, a multivariate effect of time (6-8 years: $F=9.976$, $P<0.001$; 8-10 years: $F=2.260$, $P=0.030$), sex (6-8 years: $F=8.866$, $P<0.001$; 8-10 years: $F=18.313$, $P<0.001$) and MQgroup (6-8 years: $F=11.082$, $P<0.001$; 8-10 years: $F=11.563$, $P<0.001$) was revealed. The covariate age was a significant confounding factor throughout the analysis. Univariate statistics were further analysed to describe the abovementioned effects.

For sit and reach, no univariate time*MQgroup*sex or time*MQgroup interaction effects were found. A significant effect of sex and MQgroup on sit and reach test scores was found in both age cohorts, indicating that girls were more flexible than boys and MQHI children were more flexible than MQLOW children. MQHI and MQLOW groups were not significantly different from the MQAV group.

For strength variables in the youngest age cohort, no univariate time*MQgroup*sex or time*MQgroup interaction effects were found. A significant time effect was found for sit-ups, knee push-ups and standing broad jump demonstrating that performances on these tests improve over time, regardless of sex and MQgroup. A effect of sex was found for knee push-ups, hand grip strength and standing broad jump, with boys scoring better on all tests over time. MQgroup significantly influenced scores on these strength items. For all strength tests, regardless of sex and time, MQHI children performed better than MQLOW children. Except for sit-ups, the MQAV group had significantly lower scores than the MQHI group and better scores than the MQLOW group. In the oldest age cohort, a univariate time effect was found for handgrip strength only, showing that in the oldest age cohort only handgrip strength improved significantly over time. A sex effect was found for all strength variables, with boys performing better than girls on all strength tests. A main effect of MQ group showed that, regardless of sex and time, children in the MQLOW group had significantly lower scores on sit-ups, knee push-ups and standing broad jump than MQHI children. MQHI children had significantly better scores than MQAV children on sit-ups, knee push-ups, handgrip strength and standing broad jump. The MQAV reported better scores than the MQLOW group on knee push-ups and standing broad jump.

For 10x5m shuttle run in both age cohorts, a time*MQgroup*sex effect was found. It was apparent that in the youngest age cohort, MQLOW boys showed a greater 10x5m shuttle run performance increase (13.0%) than MQLOW girls (9.8%), while MQAV girls seem to have a greater performance increase (11.1%) over time than MQAV boys (7.8%). The change in performance in MQHI groups over time was similar between boys (7.4%) and girls (8.4%). In the oldest age cohort, MQAV boys (12.6%) and MQHI girls (4.5%) showed greater performance increases over time than MQAV girls (4.8%) and MQHI boys (2.3%) respectively (Figure 1). Performance differences between MQLOW boys (9.5%) and girls (9.2%) were not found. Furthermore, there was a significant time*MQgroup interaction effect in both age cohorts. It was apparent that in the youngest group the performance increase over time was greater in MQLOW than in MQAV and MQHI children. In the oldest age cohort, both MQLOW and MQAV groups showed a greater performance increase than MQHI children. Furthermore, significant univariate effects of time, sex and MQgroup were found in both age cohorts. These effects revealed that performance on the 10x5m shuttle run improved over time, boys performed better than girls and MQHI children outperformed MQLOW and MQAV children in both age cohorts.

No time*MQgroup*sex or time*MQgroup interaction effects were found on endurance shuttle run performance, but a main effect of time, sex and MQgroup in both age cohorts was found. Performances improved over time, boys had better scores than girls and the MQHI group scored better than the MQLOW group in the youngest age cohort and better than the MQLOW and MQAV children in the oldest age cohort.

Table 3: Mean±SD of the MANCOVA for physical fitness variables in different motor competence groups in 6-8 and 8-10 year old boys and girls

	Boys						Girls						*F*-values					
	Baseline			Baseline +2 years			Baseline			Baseline +2 years								
	MQLOW	MQAV	MQHI	MQLOW	MQAV	MQHI	MQLOW	MQAV	MQHI	MQLOW	MQAV	MQHI	Time	MQgroup	Sex	ime*MQgrou	e*Sex*MQgr	Covariate
Age Cohort 1	*N* = 34	*N* = 42	*N* = 32	*N* = 34	*N* = 42	*N* = 32	*N* = 34	*N* = 26	*N* = 28	*N* = 34	*N* = 26	*N* = 28						
Sit and reach (cm)	20.0±3.7	21.2±3.8	21.7±3.3	17.4±6.3	18.5±5.1	21.0±6.8	21.8±4.6	23.3±3.2	23.6±4.5	19.9±5.1	21.3±5.1	21.6±5.9	1.995	4.932**	10.994**	0.846	0.720	0.042
Sit-ups (n/30s)	11.9±7.7	14.3±8.1	17.5±9.0	20.6±6.5	19.8±7.1	23.6±6.8	12.9±7.3	13.2±5.8	16.5±5.9	18.9±6.9	22.0±7.3	23.4±6.1	31.457**	7.369**	0.027	0.090	2.178	9.295**
Knee push-ups (n/30s)	17.9±5.1	19.8±5.1	22.3±4.9	22.5±4.3	24.2±5.8	27.1±5.9	17.5±5.2	19.0±5.4	21.7±4.4	19.6±4.1	23.0±4.9	24.5±6.3	14.586**	19.303**	6.371*	0.413	0.301	3.022
Hand grip (kg)	12.2±2.8	14.2±3.8	15.1±3.3	14.3±4.2	14.8±5.3	16.4±4.6	12.1±3.4	12.4±3.4	13.4±4.4	12.7±3.5	14.0±3.0	14.2±3.8	0.554	6.081**	6.234*	0.129	1.352	39.008**
Standing broad jump (cm)	96.0±16.9	114.0±14.4	121.9±15.1	135.0±16.1	142.7±16.7	151.3±14.9	93.7±13.2	101.4±17.6	117.9±17.2	121.6±17.0	136.2±16.1	148.0±17.1	27.452**	61.452**	13.345**	0.366	2.892	22.301**
10x5m shuttle run (s)	26.1±1.7	24.3±1.6	22.9±1.6	22.7±1.4	22.4±1.4	21.2±1.1	26.5±2.5	25.3±1.5	23.8±1.2	23.9±1.6	22.5±1.1	21.8±1.1	20.606**	70.173**	14.263**	4.910**	3.338*	24.225**
Endurance shuttle run (mi	3.4±1.6	3.8±2.0	4.9±1.8	5.0±1.9	5.7±2.2	6.5±2.0	2.5±1.3	2.4±0.8	3.3±1.4	3.8±1.6	4.7±1.9	5.1±2.4	8.364**	11.848**	34.970**	1.264	0.501	6.236*
Age Cohort 2	*N* = 52	*N* = 56	*N* = 52	*N* = 52	*N* = 56	*N* = 52	*N* = 44	*N* = 46	*N* = 55	*N* = 44	*N* = 46	*N* = 55						
Sit and reach (cm)	16.8±6.3	18.4±6.2	19.1±5.3	15.8±6.4	15.6±7.2	17.1±7.2	22.0±4.4	22.8±5.6	23.6±5.7	18.6±6.8	20.6±6.4	21.9±6.9	2.363	3.839*	50.524**	0.319	1.688	0.062
Sit-ups (n/30s)	18.2±6.6	19.7±6.5	21.6±6.2	22.7±7.2	25.2±5.7	26.7±7.6	18.5±5.3	19.9±5.6	21.9±5.8	22.3±5.8	22.0±7.1	27.2±7.2	1.332	14.371**	0.211	1.093	1.875	11.119**
Knee push-ups (n/30s)	22.0±5.1	25.2±4.5	27.2±5.0	23.4±6.3	25.1±6.6	27.9±9.0	20.1±4.7	22.4±4.7	23.5±4.0	21.2±5.3	22.6±5.6	26.0±5.1	0.106	28.734**	27.032**	1.477	0.565	0.424
Hand grip (kg)	18.9±4.1	18.5±3.7	19.0±3.3	16.4±4.4	17.9±4.5	17.6±4.3	17.1±3.7	16.2±2.8	17.4±3.0	17.0±3.9	16.3±4.3	16.7±4.4	7.380**	0.479	12.082**	1.327	1.002	9.967**
Standing broad jump (cm)	118.2±15.0	127.8±14.1	141.1±15.3	141.9±19.0	147.0±17.2	157.9±22.1	113.7±15.8	125.1±12.2	135.6±13.0	138.1±18.9	143.4±16.5	156.4±16.6	0.668	59.196**	5.250*	2.280	0.397	7.450**
10x5m shuttle run (s)	24.3±2.1	22.7±1.4	21.4±1.0	22.0±1.6	20.9±3.1	20.9±1.4	24.9±2.0	23.1±1.4	22.2±1.0	22.6±1.5	22.0±1.4	21.2±1.2	5.786*	57.714**	16.634**	13.887**	3.561*	7.195**
Endurance shuttle run (mi	3.9±2.0	4.9±1.7	6.9±2.6	5.2±2.5	6.2±2.4	6.9±2.6	3.2±1.6	3.8±1.7	4.1±1.7	4.1±1.7	5.0±2.4	5.8±2.3	0.467	23.847**	41.298**	0.112	2.040	1.129

*Note: * = P<0.05, ** = P<0.01; MQLOW = relatively low motor competence, MQAV = relatively average motor competence and MQHI = relatively high motor competence. Age Cohort 1: 6.00-7.99 years old as baseline testing, Age Cohort 2: 8.00-9.99 years old at baseline testing*

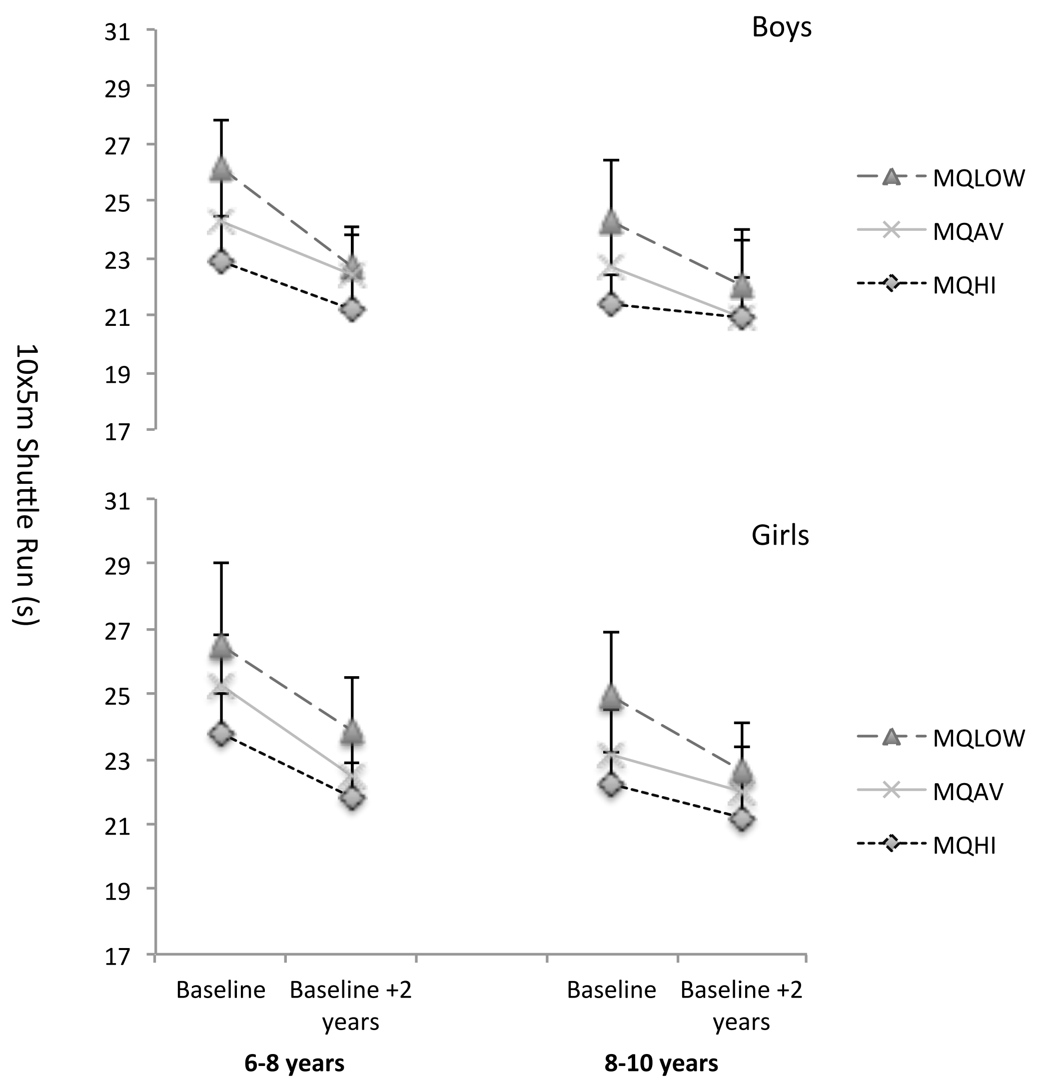

Figure 1: Changes over a two-year period in 10x5m shuttle run performance for boys and girls from two age cohorts

*Note: There are significant time*sex*MQgroup (P<0.05) and time*MQgroup (P<0.01) interactions in both age cohorts. Age Cohort 1: 6.00-7.99 years old at baseline testing, Age Cohort 2: 8.00-9.99 years old at baseline testing*

None of the ANOVAs revealed significant time*MQgroup*sex or time*MQ group interaction effects in any of the age cohorts (Table 4). A significant effect of time was found in the youngest age cohort on total time spent in sports and time spent in club-level participation, which means that over time, children spend increasing amounts of time in sports in general and sports at a club-level in particular. In the oldest age cohort, a main effect of MQgroup on total time spent in sports and time spent in sports participation at a club level was revealed. It appeared that MQHI children from the oldest age cohort had spent more total time in sports and more time in club-level sports participation than their MQLOW peers. MQAV children did not report significantly different sports participation from MQLOW or MQHI children.

Table 4: Mean±SD of three ANOVA's for measures of time spent in sports participation in 6-8 and 8-10 year old boys and girls

	Boys						Girls						*F*-values				
	Year 1			Year 3			Year 1			Year 3							
	MQLOW	MQAV	MQHI	MQLOW	MQAV	MQHI	MQLOW	MQAV	MQHI	MQLOW	MQAV	MQHI	Time	MQgroup	Gender	Time*MQgroup	Time*Gender*MQgroup
Age Cohort 1																	
Total time (Hours/week*m	21.7±14.8	26.1±17.4	22.9±21.4	29.5±16.2	34.6±15.3	36.7±28.5	20.7±13.4	24.5±19.5	18.9±12.6	28.5±28.8	34.6±15.3	16.7±8.9	4.358*	0.733	5.156	0.093	0.615
Club (Hours.week)	2.5±1.7	2.4±1.1	2.2±1.8	2.7±1.1	3.5±1.7	3.5±2.7	1.9±1.1	2.3±1.9	2.1±1.3	2.9±2.9	2.2±1.0	1.8±1.0	4.067*	0.200	4.851	0.007	1.357
Age Cohort 2																	
Total time (Hours/week*m	34.2±24.0	32.2±17.8	31.8±16.1	29.3±14.1	27.5±15.4	37.8±24.4	20.7±8.3	27.5±15.4	36.3±3.8	20.8±15.2	27.9±17.6	41.2±31.7	0.173	3.514*	1.339	0.655	0.092
Club (Hours.week)	3.0±1.4	3.1±1.7	3.4±1.6	2.8±1.5	3.5±2.6	3.7±2.4	2.2±0.8	2.6±1.5	3.4±2.3	2.2±1.7	2.9±1.8	3.9±2.8	0.582	3.437*	1.150	0.255	0.028

*Note: * = P<0.05, ** = P<0.01; MQLOW = relatively low motor competence, MQAV = relatively average motor competence and MQHI = relatively high motor competence. Age Cohort 1: 6.00-7.99 years old as baseline testing, Age Cohort 2: 8.00-9.99 years old at baseline testing*

Discussion

This research aimed to investigate the difference in changes in physical fitness over a two-year time span between 6-10 year old children with a relatively high, moderate or low motor competence. An additional aim of this study was to investigate the difference in sports participation between these motor competence groups over the two year time span of this study. The first main finding was that children with a higher motor competence outperformed children with a lower motor competence on all physical fitness tests. These differences remained similar over time for most measures of physical fitness, except for 10x5m shuttle run performance (i.e., greater performance increase for the children in the MQLOW and/or MQAV group). Furthermore, no difference in the change in sports participation between MQLOW, MQHI and MQAV groups was found. However, children with a high motor competence were more involved in club level sports participation and total time spent in sports than children from the low motor competence group.

The findings in the current study are in accordance with Hands (2008), who showed that low motor competent children had lower performance scores on most fitness items, and Cairney et al. (2011) who showed lower scores on a 20m shuttle run test in children with DCD than in typically developing children. However, neither of these studies observed between-group differences in changes in physical fitness over time. Accordingly, Hands (2008) concluded that children with low motor competence and low levels of physical fitness at a young age, are unlikely to catch up with their peers over time, which is confirmed by the results reported in this study. Not only do children with a relatively low motor competence possess lower physical fitness levels than children with a high motor competence, but this study shows that in a general population, children with relatively low motor competence have lower fitness levels than children with an average motor competence.

Cantell et al. (Cantell et al., 1994) suggested that children with relatively severe movement difficulties continue to experience movement related difficulties into adolescence and possibly adulthood, and that their difficulties may even increase with age. The current study found no evidence of such an increase in favour of the MQHI over the MQLOW group in an age cohort of 4 years with a follow-up of two years. Only the 10x5m shuttle run had different changes over time between groups. However, these changes were in favour of the MQLOW group: a greater performance increase over time for MQLOW than for MQAV or MQHI children was observed. The lack of evidence to support the findings by Cantell et al. (1994) might be due to the difference in age between this test-sample (5-15 years) and the sample used in the present study (6-10 years) suggesting that motor competence difficulties may increase as children enter adolescence. Hands (2008) also reported similar findings for cardiovascular endurance, 50m run and a balance test, where a low motor competence group had the greatest performance improvement over time. In 1987, Erhardt et al. (1887) suggested that children with low motor competence take longer to reach a personal performance ceiling than children with high motor competence, resulting in a greater increase in particular measures of physical fitness over time for low motor competent children at specific periods in their development. This would imply that, at certain stages in athletic development that are driven by motor competence, differences in physical fitness between children with a high and low motor competence would be great. At other stages of athletic development however, where the influence of motor competence is low, differences in physical fitness between children with a low and high motor competence would be smaller. This implies a critical time in the development of motor competence and could help to explain the time*MQgroup interaction effect for 10x5m shuttle run performance. Cratty (1986) suggested that a critical window for the development of motor competence could be around 9-10 years. However, no fluctuations in differences between MQLOW and MQHI children over the two-year time span of the study were found for physical fitness in general. Therefore, the findings in this study show that between the age of 6-10 with low motor competence maintain their deficit in overall physical fitness over time compared to children with high motor competence.

We hypothesized that a difference in sports participation between MQHI and MQLOW children would be apparent, and that this difference would increase with time, especially in the oldest age cohort. While we did find a difference in total time spent in sports participation and time spent in club-level sports participation, no time*MQgroup interaction effect was found. This means that although between group differences were found, they did not change over time and therefore only partly confirmed our hypothesis that differences between motor competence groups would increase over time. A possible explanation for this could be that motor competent children participate in sports more often than children with low motor competence because the latter have been found to have negative experiences in physical activity in general and have developed strategies to avoid it (Fitzpatrick & Watkinson, 2003; Cairney et al., 2005; Kirby et al., 2005). A second explanation could be a reduction in perceived motor competence (Rose et al., 1997), confidence and motivation (Rose et al., 1998) to participate in physical activity in children with motor difficulties that results in a withdrawal from physical activity opportunities, described as the 'activity deficit' phenomenon (Bouffard et al., 1996). An increased withdrawal from or decrease in physical activity over time was not observed in the current study and might be due to the tools used to measure total physical activity. That is, this study used the total time spent in sports participation (competitive and recreational) and club level sports participation and excluded children with sports participation (Children not participation in sports at MQLOW baseline: 27%, baseline +2: 26%; MQAV baseline: 17%, baseline +2: 22%; MQHI baseline: 14%, baseline +2: 15%). This study can therefore only conclude on the effect of time spent in sports participation and not on physical activity as a whole.

There were some limitations to this study. The first is the inability to include a measure for physical activity or multiple physical activity subdomains rather than sports participation alone, since the mediating role of physical activity in the association between motor competence and physical fitness has already been established (Cairney et al., 2005b; 2006). The second shortcoming is the relatively high dropout rate: 1324 subjects dropped out between baseline and baseline +2 and an additional 223 did not fill in the questionnaire on both testing occasions. Gross motor competence was not different between groups, but table 2 did show significant differences in physical fitness variables between the test and drop out sample. Although differences were not systematically in favor of one group, this should be acknowledged as a shortcoming in this study. Furthermore, other factors such as psychosocial factors that might affect physical fitness (Skinner & Piek, 2001) were not assessed but may have influenced the differences in physical fitness between the test and drop out sample in this study. The strengths of the present study are its large sample size, representative for the general Flemish population (Vandorpe et al., 2011) between 6-10 years old, the coverage of a large age span of both boys and girls and the comparison of three relative motor competence groups (high, average and low motor competence) rather than comparing typically and atypically developing children. Furthermore, the current study was the first study that longitudinally investigated the effect of motor competence on physical fitness and sports participation in 6-10 year old children. Finally, future research should attempt to investigate the interrelationships between measures of physical fitness, motor competence, physical activity and perceived competence since perception of adequacy regarding motor tasks has also mentioned as a mediator in the relationship between motor competence and physical fitness.

In conclusion, children with a relatively high motor competence compared with their peers, show similar changes in physical fitness variables to children with a relatively average or low motor competence. Highly motor competent children achieve better physical fitness scores on both baseline and baseline + 2 years testing occasions. This implies that although children with a low motor competence also show significantly changes in physical fitness over time, they don't acquire physical fitness levels of average or high motor competence children and are at risk of maintaining their relatively low physical fitness levels over time. Furthermore, children with a relatively high motor competence are more involved in sports than children with a lower motor competence. These differences did not increase over time. Since children with a high motor competence show better physical fitness levels and a greater participation in sports, it might be that highly motor competent children are able to better cope with the demands of participation in sporting activities. Therefore, they have more opportunities to further develop their physical fitness and motor competence, possibly further increasing the differences between children with a low, average and high motor competence.

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CHAPTER III: SPECIALISATION VS DIVERSIFICATION

STUDY 4:

Differences in physical fitness and motor competence in boys aged 6-12 specialising in one versus sampling more than one sport.

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Abstract

The Developmental Model of Sports Participation proposes two pathways towards expertise in sports between 6 and 12 years of age: early specialisation and early diversification. This study investigated the effect of sampling various sports and of spending many or few hours in sports on fitness and motor competence. Altogether, 735 boys in three age groups (6– 8, 8–10, and 10–12 years) were profiled using a fitness test battery. A computerized physical activity questionnaire was used to obtain data on sports participation. In the eldest group, (M)ANCOVA showed a positive effect of sampling various sports on strength, speed, endurance, and motor competence (P5 < 0.05). A positive effect of many hours per week spent in sports was apparent in every age group. These data suggest an acute positive effect of many hours in sports and a latent positive effect of early sampling on fitness and motor competence Multiple comparisons revealed that boys aged 10– 12 years, who spent many hours in various sports, performed better on standing broad jump (P < 0.05) and motor competence (P < 0.05) than boys specialising in a single sport. Therefore, our results highlight the importance of spending many hours in sports and sampling various sports in the development of fitness and motor competence.

Introduction

Many studies have attempted to model the trajectory of motor abilities from childhood towards adult expert performance. Research has focused on two distinctive pathways in this development process. The first is a performance-centred pathway with the amount of domain-specific practice as the sole contributor of expert performance (Ericsson et al, 1993; Helsen et al., 1998; Ward et al., 2004; 2007). The second is a pathway implementing different stages of athletic development before reaching an expert level (Bompa & Haff, 2009; Côté, 1999; Côté et al., 2003; 2007; Côté & Fraser-Thomas, 2007). The latter is the focus of this study, since it promotes general athletic development through sampling various sports before beginning to specialise in one sport.

In their Developmental Model of Sports Participation (DMSP), Côté and colleagues showed two pathways towards elite performance in sports: early diversification and early specialisation (Côté, 1999; Côté et al., 2003, 2007; Côté & Fraser-Thomas, 2007). Ericsson et al. (1993) provide support for the early specialisation pathway by showing that 10,000 h of accumulated structured and organized practice called ‘‘deliberate practice’’ are needed to reach an expert level of performance in most sports. Therefore, early specialising athletes enter their primary sport at an early age and participate in a high amount of deliberate practice in their primary sport with almost no deliberate play in any other sports (Ford et al., 2009)

In the early diversification approach, the DMSP introduced three stages of athlete development: the sampling stage (6–12 years), the specialising stage (12–15 years), and the investment stage (+15 years). During the sampling stage, young athletes participate in various sports (Côté, 1999) and engage in many deliberate play activities designed to maximize enjoyment through less structured play and age-adapted rules. Sampling is considered beneficial for athletic development because of the exposure to a number of different physical, cognitive, affective, and psycho-social environments, reinforcing physical, personal, and mental skills needed for future successful sport specialisation (Côté et al., 2009). In a study involving elite athletes in field hockey, basketball, and netball, Baker and colleagues (Baker et al., 2003) reported that athletes who required fewer hours of sports-specific practice to attain expertise had participated in many sports activities prior to reaching an expert level. Furthermore, expert triathletes (Baker et al., 2005) had participated in more hours in different sports activities prior to starting triathlon than their non-expert counterparts, who generally finish at the back of the pack. Also, 6- to 8-year-old ice-hockey players participated in an average of three and 9- to 12-year-old ice hockey players even in up to six sports other than their primary sport during the sampling years (Soberlak & Côté, 2003). Vaeyens and colleagues (Vaeyens et al., 2009) also found that Olympic world-class athletes started training, competing, and participating in international competitions later and competed in more sports other than their primary sport than peers performing at a national level. Therefore, Côté and colleagues (2009) concluded that a sampling stage did not hinder future expert performance.

Following the sampling stage (12+ years), the DMSP (Côté, 1999; Côté et al., 2003, 2007; Côté & Fraser-Thomas, 2007) proposed two different trajectories. In the first, children are introduced to recreational sports participation with a focus on enjoyment and health benefits. The second trajectory involves children specialising in the adolescent years (13–15 years) and investing in just one sport at the age of 15– 16 years. At this age, physical, cognitive, social, emotional, and skill development reaches its peak and allows athletes to start highly specialised training in a single sport with the main goal of improving performance (Patel et al., 2002).

A clear distinction between the advantages and disadvantages of early specialisation and early diversification has been made (Bompa & Haff, 2009; Hecimovich, 2004). Specialisation at an early age leads to faster target sport performance improvement and peak performance at the age of 15–16 years

(Bompa & Haff, 2009). However, early specialising athletes often burn out because of repetitive strain (Gould et al., 1996) and a decrease in intrinsic motivation and enjoyment during their training sessions (Wall & Côté, 2007). Furthermore, early specialising athletes are at risk of social isolation, over-dependence, and overuse injury (Malina, 2010). Early diversifying athletes reach peak target sport performance at a slower rate and at a later age (Baker et al., 2003), but fewer appear to drop out (Fraser-Thomas et al., 2008) and they sustain fewer injuries (Bompa & Haff, 2009) than early specialising athletes because of a more gradual physical and psychological development (Côté et al., 2009). Also, athletes who had diversified early showed longer adherence to adult sports participation and had longer athletic careers (Baker et al., 2005). In 2000, the American Academy of Paediatrics (2000, p. 1) made a strong statement on early specialisation: ‘‘Children involved in sports should be encouraged to participate in a variety of different activities and develop a wide range of skills. Young athletes who specialise in just one sport may be denied the benefits of varied activity while facing additional physical, physiological and psychological demands from intense training and competition’’.

To date, no research has investigated the differences in anthropometry, physical fitness, and motor competence between children participating in just one versus more than one sport from an early diversification versus early specialisation point of view. Therefore, the profiling of sampling and specialising 6- to 12-year-old boys might provide more insight into the effect of sampling various sports on these performance-related characteristics.

The main aim of this study was to examine differences in anthropometry, physical fitness, and motor competence in 6- to 12-year-old boys participating in just one versus more than one sport in an organized and recreational context. We also wished to determine whether boys participating in many hours of sports per week in various sports activities possess better physical fitness and motor competence It was hypothesized that a positive effect of sampling various sports on physical fitness and motor competence would become more apparent in the older age groups, and that the positive effect of many hours spent in sports would be apparent from a young age. Furthermore, it was also hypothesized that boys accumulating a high amount of training hours per week in more than one sport would possess better physical fitness and motor competence.

Methods

Study design and participants

The present research had a cross-sectional design involving three age groups (6–8, 8–10, and 10–12 years). Children from nine sports clubs involved in the

SPORTAKUS project as well as 26 primary schools for general education throughout the Flemish part of Belgium involved in the ‘‘Flemish Sports Compass’’ (Vandorpe et al., 2011) participated in the study. This resulted in the profiling of the anthropometry, strength, flexibility, speed and agility, cardiovascular endurance, and motor competence of 1162 children aged 6–12 years. Since no differences between the sexes were targeted in this study and to ensure sufficient statistical power due to the small number of girls, only boys were included. This resulted in a population of 735 boys aged 6–12 years: 161 boys aged 6–8 years, 310 boys aged 8–10 years, and 264 boys aged 10–12 years. 220 boys eventually dropped out of the study due to incomplete testing data, which resulted in a population of 615 boys (Table 1). The study received approval from the local ethics committee of Ghent University Hospital. Written informed consent was obtained from the parents or guardians of the children.

Table 1. The time (hours:minutes) spent in sports per week by single sports participants and multiple sports participants (mean + s, median).

		Single Sports Participants (n = 323)			Multiple Sports Participants (n = 192)	
Age Group		mean ± s	median		mean ± s	median
6-8 years	n = 59	2:42 ± 1:18	03:00	n = 40	4:18 ± 1:54	04:00
8-10 years	n = 151	3:42 ± 1:42	04:00	n = 81	5:36 ± 2:24	05:30
10-12 years	n = 113	4:12 ± 1:54	04:00	n = 71	5:42 ± 2:18	06:00

Measurements

A test battery for anthropometric profiling and the assessment of basic performance characteristics was used to obtain test data for each participant. The test battery included measuring body mass and height and tests used in the Eurofit Physical Fitness Test Battery (EUROFIT, 1988), the Bruininks-Oseretsky Test of Motor Proficiency 2 (Bruininks & Bruininks, 2005), and the Ko¨rperkoor- dinationsTest fu¨ r Kinder (Kiphard & Schilling, 1974). Height was measured to the nearest 0.1 cm using a portable stadiometer (Harpenden Portable Stadiometer, Holtain, Crymych, UK) and body mass using a digital weighing scale (TANITA BC- 420SMA, Tokyo, Japan). Muscular strength and strength endurance for all participants was assessed using the BOT2 sit- ups and knee push-ups test. Maximal static strength data and explosive strength were obtained using the EUROFIT handgrip strength test and standing broad jump. Hamstring and lower back flexibility was assessed by the EUROFIT sit-and-reach test. Speed and agility were measured by the EUROFIT 10x5m shuttle run test. Cardiovascular endurance was measured by the EUROFIT endurance shuttle run test. Data for motor competence were obtained using the KTK (Kiphard & Schilling, 1974), which consists of four sub-tests: walking backwards along a balance beam, moving sideways on boxes, hopping for height on one foot, and jumping sideways. Scores for motor competence were obtained through the transformation of the raw data of four KTK sub-tests into an age- and gender- specific motor quotient. In a general population, a motor quotient between 86 and 115 points indicates typically developing coordination (Kiphard & Schilling, 1974). For an elaborate description of the above tests, see Vandorpe et al. (2011). A team of specifically trained supervisors scored each test. All tests were performed in bare feet and in a similar environment (indoor sports infrastructure) and were conducted over a 3-month period.

The nature of the sport(s) the boys participated in (type of sport, club membership, frequency of training) and the total time spent in recreational physical activity and in organized sports during the year in which the testing took place were obtained through self-reported physical activity assessment using the Flemish Physical Activity Computerized Questionnaire (Philippaerts et al., 2006). Due to the relatively young age of some of the participants, the questionnaire was completed with the help of their parents or guardians. Boys reporting participation in only one sport during the year in which the testing took place were labelled ‘‘single sport participants’’ and those reporting more than one sport were considered ‘multiple sports participants’. The median for their respective age group was used to determine whether single sport participants and multiple sports participants spend many or few hours per week in sports. This subdivision resulted in the creation of four subgroups: single sports participants involved in few hours of sport per week; single sport participants involved in many hours of sport per week; multiple sports participants involved in few hours of sport per week; and multiple sports participants involved in many hours of sport per week.

Data analysis

The effect of the number of sports and of the amount of hours per week spent in sports. All data were analysed using SPSS v.15.0. To determine the effects of participating in one versus more than one sport and of participating in few or many hours of sports per week on anthropometry, physical fitness, and motor competence a two-way multivariate analysis of covariance (MANCOVA) with a Bonferroni correction for multiple comparisons was used. The number (one or more than one) of sports participated in and the amount of hours per week spent in sports were used as fixed factors, the test variables as dependent variables, and chronological age as a covariate. Differences in test scores between the four subgroups. A post-hoc analysis consisting of a two-way MANCOVA with a Bonferroni correction for multiple comparisons was used to compare the test scores of the four subgroups (single sport participants involved in few hours of sport per week; single sport participants involved in many hours of sport per week; multiple sports participants involved in few hours of sport per week; and multiple sports participants involved in many hours of sport per week) for anthropometry, physical fitness, and motor competence. The subgroups were considered as fixed factors, the test variables as dependent variables, and chronological age as a covariate. For all analyses, statistical significance was set at $P < 0.05$.

Results

Results (mean + s, univariate F-values, and covariate F-values) of the two-way MANCOVA are reported in Table II for the three age groups separately.

Covariate

Age appeared to be a significant covariate in all age groups ($P < 0.01$). No significant multivariate interaction effect was found in any of the age groups. MANCOVA revealed a significant multivariate effect of the number of sports in the 10–12 year age group ($F = 2.107$, $P = 0.026$) on measures of anthropometry, physical fitness, and motor competence. Furthermore, a significant multivariate effect was found for the number of hours spent in sports per week in the 8–10 year age group ($F = 2.145$, $P = 0.022$) and the 10–12 year age group ($F = 2.456$, $P = 0.009$) on anthropometry, fitness, and motor competence.

MANOVA

A two-way MANCOVA showed no significant interactions for body mass or height. There was also no main effect of the number of sports or the hours spent in sports per week for any of the age groups.

No significant interaction effect of the number of sports and the hours spent in sports per week were found for knee push-ups, sit-ups, handgrip strength or standing broad jump in any of the age groups. A significant effect of the number of sports on handgrip strength was revealed for the 6–8 year age group and on knee push-ups and standing broad jump for the 10–12 year age group. Boys participating in more than one sport scored better on these tests than boys participating in only one sport. A significant effect of the hours spent in sports per week on standing broad jump performance was observed in all age groups. Boys who spent many hours per week in sports jumped further than boys who spent few hours per week in sports. According to the post-hoc analysis, in the 6–8 year age group, multiple sports participants involved in many hours of sport per week had significantly better handgrip strength than single sport participants involved in few hours of sport per week. Furthermore, in the 8–10 year age group, single sport participants involved in many hours of sports per week performed significantly better on the standing broad jump than single sport participants involved in few hours of sport per week. In the 10–12 year age group, multiple sports participants involved in many hours of sport per week outperformed all other groups (Figure 1A).

ANOVA

No significant interaction effect was found for the sit- and-reach test in any of the age groups. And no main effect of the number of sports was found for any of the groups. In the 10–12 year age group, a significant effect was observed of the hours per week spent in sports on sit-and-reach performance. Boys who spent many hours per week in sports performed better on the sit-and-reach test than those who spent few hours per week in sports.

For the 10 6 5-m shuttle run (SHR) test, no significant interaction effect was found in any of the age groups. A significant effect of the number of sports on SHR test performance was observed for the 10– 12 year age group. Boys participating in more than one sport were faster than boys participating in only one sport. A significant effect of hours per week spent in sports on SHR test performance was observed for the 8–10 year age group. Boys who spent many hours per week in sports were significantly faster than boys who spent few hours per week in sport. In the 8–10 year age group, single sport participants with many hours of sport per week were significantly faster than those reporting few hours per week. In the 10–12 year age group, multiple sports participants who spent both few and many hours in sports per week were significantly faster than single sport participants who spent a few hours in sports per week.

No significant interaction effect on endurance shuttle run performance was apparent in any age group. In the eldest age group, a significant effect of the number of sports on endurance shuttle run (ESHR) performance was observed. Boys participating in more than one sport showed better cardiovascular endurance than boys participating in only one sport. In the 8–10 year age group, a significant univariate effect of the hours per week spent in sports on ESHR performance was revealed. Children with many hours per week spent in sports had better cardiovascular endurance than children with few hours per week. In the 8–10 year age group, post hoc analysis revealed a significant difference in ESHR performance between single sport participants reporting few hours per week in sports and multiple sports participants with many hours per week.

There was no interaction effect apparent on motor competence. A significant effect of the number of sports on motor competence (motor quotient) was revealed in the 10–12 year age group. Boys participating in more than one sport possessed a higher motor quotient than boys participating in one sport. An effect of the hours spent in sports per week on motor quotient was observed in all age groups. In all age groups, boys who spent many hours per week in sports possessed a higher motor quotient than boys spending few hours in sports per week. In the 8– 10 year age group, post-hoc analysis revealed that single sport participants reporting few hours per week in sports had a significantly lower motor quotient than single sport participants and multiple sports participants with many hours per week. In addition, in the 10–12 year age group, multiple sports participants with many hours per week had a significantly higher motor quotient than all other groups (Figure 1B).

Table 2: Results for anthropometry, physical fitness, and motor competence in the three age groups separately for single (SSP) and multiple sports participants (MSP) (Mean ± s plus *F*-values)

	SSP		MSP		*F*-values			
Age group	Few hours	Many hours	Few hours	Many hours	No. sports (NS)	Hours per week (HW)	NS*HW	Covariate
6–8 years	(*n* = 39)	(*n* = 20)	(*n* = 23)	(*n* = 17)				
Body mass (kg)	24.9±3.7	24.9±3.2	25.7±5.0	25.9±3.4	1.968	0.223	0.114	20.534**
Height (cm)	125.8±6.0	125.6±7.2	125.6±7.2	128.1±6.5	1.676	0.154	0.397	51.243**
SAR (cm)	20.5±4.6	19.8±6.6	18.3±5.6	20.5±4.3	0.440	0.440	1.811	0.024
KPU (*n*/30 s)	19.4±6.1	20.9±5.4	20.8±5.6	22.1±6.9	1.579	0.493	0.222	23.583**
SUP (*n*/30 s)	16.0±7.3	14.5±6.2	14.0±9.2	16.8±8.6	0.042	0.006	1.161	10.955**
HGR (kg)	14.3±3.4[a]	14.7±2.7[a,b]	14.7±3.4[a,b]	17.3±4.5[b]	5.673*	3.586	1.685	19.406**
SBJ (cm)	119.7±19.8	123.5±115.3	117.3±17.8	133.2±22.0	0.480	5.298*	1.582	40.718**
SHR (s)	24.2±2.1	23.1±1.5	23.6±1.7	23.6±2.9	0.064	0.759	2.604	13.568**
ESHR (min)	4.9±2.3	4.9±2.3	5.0±2.1	5.2±2.3	0.352	0.124	0.015	19.139**
MQ (points)	101.6±14.4	107.8±13.9	101.0±13.7	110.1±12.7	0.216	5.822*	0.024	22.991**
8–10 years	(*n* = 119)	(*n* = 32)	(*n* = 43)	(*n* = 38)				
Body mass (kg)	30.2±5.6	32.1±4.0	30.1±3.8	30.1±5.4	1.423	1.426	1.003	15.006**
Height (cm)	135.0±7.0	137.2±4.6	135.5±5.2	135.6±6.8	0.100	1.434	0.452	41.131**
SAR (cm)	18.5±5.5	18.7±4.8	18.7±5.9	20.3±4.5	1.193	1.446	0.615	2.731
KPU (*n*/30 s)	24.8±5.6	27.2±5.4	27.0±6.1	27.0±5.8	1.198	1.869	1.948	0.236
SUP (*n*/30 s)	20.7±5.8	22.6±5.9	22.2±6.5	23.6±7.1	1.909	2.851	0.024	2.371
HGR (kg)	18.3±3.4	19.1±2.9	19.2±3.3	19.3±3.2	1.777	0.772	0.073	18.782**
SBJ (cm)	135.5±17.5[a]	145.7±17.2[b]	139.7±18.4[a,b]	143.2±16.3[a,b]	0.141	6.749*	1.510	1.066
SHR (s)	22.5±1.8[a]	21.3±1.1[b]	22.0±1.6[a,b]	21.8±1.7[a,b]	0.005	8.011**	3.294	12.587**
ESHR (min)	6.0±2.2[a]	6.8±2.2[a,b]	6.4±2.3[a,b]	7.1±1.9[b]	1.848	5.299*	0.009	8.703**
MQ (points)	99.4±12.8[a]	106.6±10.5[b]	102.4±13.4[a,b]	107.1±13.2[b]	0.860	9.775**	0.464	0.038
10–12 years	(*n* = 38)	(*n* = 75)	(*n* = 33)	(*n* = 38)				
Body mass (kg)	36.4±6.6	36.0±5.6	36.5±8.6	36.3±5.8	0.180	0.109	0.038	7.559**
Height (cm)	144.6±7.5	145.1±5.9	145.2±7.5	145.4±6.7	0.766	0.118	0.021	28.474**
SAR (cm)	15.6±4.7	18.0±5.7	16.5±5.9	18.1±4.9	0.338	5.343*	0.222	0.013
KPU (*n*/30 s)	28.2±6.4	29.3±6.6	30.1±6.2	31.0±6.4	4.197**	1.001	0.007	7.825**
SUP (*n*/30 s)	23.5±5.8	25.4±7.3	25.2±6.7	27.1±8.8	3.744	3.013	0.037	19.227**
HGR (kg)	22.8±4.0	23.4±4.4	24.0±4.1	23.7±4.3	2.410	0.070	0.274	19.992**
SBJ (cm)	147.3±17.2[a]	155.1±20.5[a]	153.1±15.7[a]	163.7±15.4[b]	8.906**	11.480**	0.570	14.487**
SHR (s)	21.7±1.5[a]	21.1±1.3[a,b]	20.8±1.3[b]	20.9±1.3[b]	10.502**	1.366	1.467	17.397**
ESHR (min)	6.6±2.9	7.7±2.3	7.9±2.1	7.9±2.0	5.650*	2.196	1.463	11.755**
MQ (points)	98.5±13.1[a]	103.4±9.9[a]	102.9±13.1[a]	110.8±10.1[b]	14.043**	14.211**	1.170	12.403**

Note: SAR, sit-and-reach test; KPU, knee push-ups; SUP, sit-ups; HGR, handgrip strength; SBJ, standing broad jump; SHR, 1065-m shuttle run test; ESHR, *endurance shuttle run test; MQ, motor quotient. *P 5 0.05; **P 5 0.01; different superscripts are significant at the 0.05 level.*

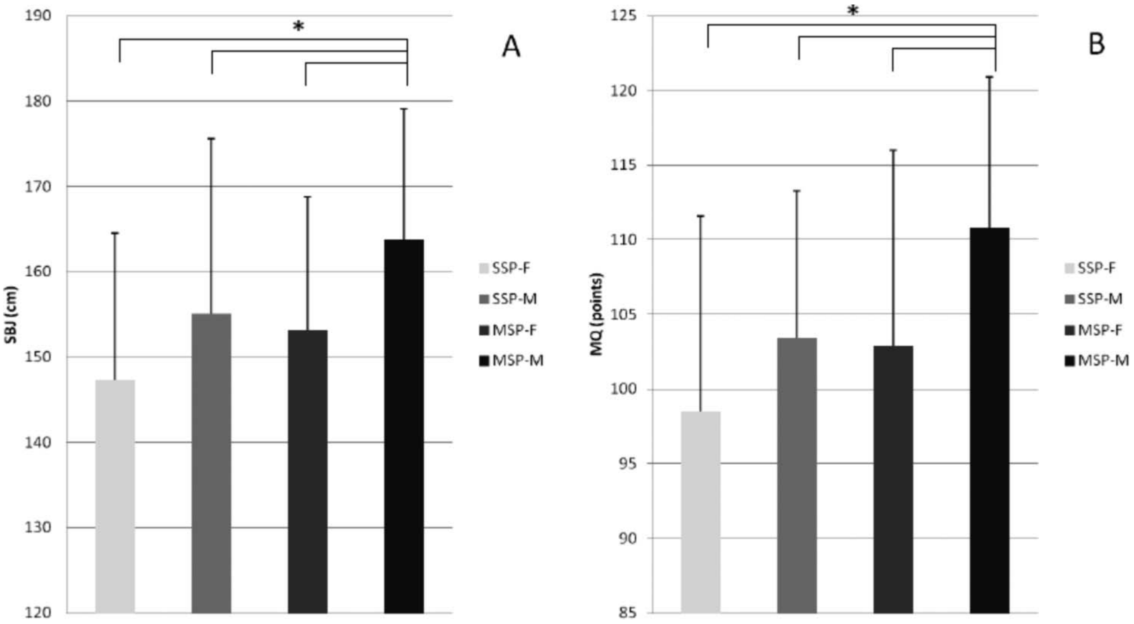

Figure 1. Differences in standing broad jump distance (SBJ, cm) (A) and motor competence (MQ, points) (B) between single sport participants and multiple sports participants who spent few or many hours per week in sports per week: 10–12 year age group.

**Significant at P < 0.05. Note: SSP-F = single sport participants/few hours per week, SSP-M = single sport participants/many hours per week, MSP-F = multiple sports participants/few hours per week, MSP-M 1⁄4 multiple sports participants/many hours per week.*

Discussion

The aims of this study were to assess differences in anthropometry, physical fitness, and motor competence between boys specialising in and sampling sports, and to determine whether boys participating in many hours of sports per week in various sports activities possess better physical fitness and motor competence.

We observed significant effects of hours per week spent in sports on standing broad jump and motor quotient in the 6–8 year age group; on standing broad jump, 10 6 5-m shuttle run test, endurance shuttle run test, and motor quotient in the 8–10 year age group; and on sit-and-reach test, standing broad jump, and motor quotient in the 10–12 year age group. The positive effect of the amount of practice on performance was established by ‘‘the power law of practice’’ introduced by Newell and Rosenbloom (1981) and later by the ‘theory of deliberate practice’ (Ericsson et al., 1993). The present study emphasizes the acute positive effect of spending many hours per week in sports. The results support the hypothesis of Bompa and Haff (2009) and Hecimovic (2004) that early specialisation is characterized by a more rapid improvement in performance in the target sport than early diversification. Furthermore, athletes specialising in just one sport or skill may become more proficient at that skill than an athlete who practises these skills periodically, as is the fact in early diversification (Wiersma, 2000). This advantage of early specialisation may be the reason many youth coaches believe that not specialising early is foolish, since athletic careers are short (Wiersma, 2000). Therefore, submitting young athletes to a stringent training regime with many hours of sports per week is a sensible choice. This is especially the case in sports where the attainment of peak performance at a young age encourages early competitive sports participation such as figure skating (Starkes et al., 1996) and gymnastics (Law et al., 2007).

In this study, differences between boys participating in just one or in more than one sport were mainly observed in the 10–12 year age group for knee push- ups, standing broad jump, 10 x 5m shuttle run test, and motor quotient. Boys participating in more than one sport performed better for each of these variables. The fact that differences were only revealed in the eldest age group is supported by the fact that when diversifying early, improvement in performance is slower than when specialising early (Bompa & Haff, 2009; Hecimovich, 2004). Also, boys participating in more than one sport were exposed to a greater number of physical, cognitive, affective, and psychosocial environments than boys participating in one sport only. As a result, these children possess a broad range of physical, personal, and mental skills needed for future successful sport specialisation during adolescence (Côté et al., 2009). These findings, however, do not necessarily imply that better physical fitness and motor competence are the direct result of sampling. It might also be that the best athletes choose to participate in more than one sport because their excellent physical fitness and motor competence allows them to cope more easily with new and challenging environments (Skinner & Piek, 2001). To establish a clear causal relationship between the sampling of more than one sport before the age of 12 and physical fitness and motor competence, longitudinal research is required.

In the 10–12 year age group, we found significant main effects of number of hours spent in sports and number of sports participated in on standing broad jump and motor quotient. The results show that the multiple sports participants with many hours per week jumped further and had a higher motor quotient than all other groups (Figure 1A, B). This suggests that in the eldest age group, in contrast with the two youngest age groups, participation in many hours of sports per week in more than one sport might be important for developing standing broad jump performance and motor competence. These data suggest that sampling various sports before the age of 12 years could be beneficial in developing strength and coordination if a sufficient amount of time is spent in sports activities. However, longitudinal research, preferably also involving children up to 16 years of age, could provide further insights in this matter. The clear advantages of this study are its sufficiently large sample size for all age groups, its representativeness of the general Flemish population, and its unique approach. This approach differs from most current research on the early diversification versus early specialisation debate through its emphasis on anthropometry, physical fitness, and motor competence and not on differences between elite and sub-elite athletes or on sport-specific measures of performance.

Finally, this study has also revealed some shortcomings. The first is an inability to separate the total amount of accumulated time in sports activities into time spent in deliberate practice or deliberate play. Ford and colleagues (2009) made this distinction, with organized sports activities characterized as 'deliberate practice' and unorganized activities as 'deliberate play'. Future research should therefore make a clear distinction between hours spent in deliberate practice and hours spent in deliberate play when investigating differences between youngsters specialising in one and those sampling more than one sport. Furthermore, not including retrospective training history for more than one year assumes that children have not changed their training history much in the course of their athletic career, thus assuming little change in sports participation over the years.

In conclusion, spending many hours in sports per week has an acute positive effect on explosive strength and motor competence from as young an age as 6–8 years. This positive effect was apparent through- out each of the age groups. However, a positive effect of sampling various sports on explosive strength, speed and agility, cardiovascular endurance, and motor competence is delayed until the age of 10–12 years, suggesting a more latent effect of participating in more than one sport on physical fitness and motor competence. Longitudinal research might provide further insights in this matter.

Recommendations

Excellent competence in general (Hands & Larkin, 2002; Schott et al., 2007) and a well-developed physical fitness in particular in, for example, soccer (Castagna et al., 2010), gymnastics (Douda et al., 2008), handball (Mohamed et al., 2009), and ice-hockey (Burr et al., 2008) seem to be important factors in the development of elite athletic performance. Based on the results of this study, spending many hours in more than one sport might be beneficial in helping to develop strength and motor competence. It is therefore important that children before the age of 12 years are encouraged by their coaches, parents, and other training professionals to participate in sports other than just their ‘primary sport’, preferably in combination with many hours per week spent in those sports. This requires awareness on the part of coaches, parents, and training professionals of the advantages and disadvantages associated with early specialisation and early diversification. The establishment of an umbrella organization such as an omnisports club is important in this matter, since it not only provides children with experience in sports other than their main sport, but also provides the opportunity to increase the number hours spent per week participating in sports.

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CHAPTER IV: SPECIALISATION IN TEAM-SPORTS – POSITION-SPECIFIC PROFILING

STUDY 5:

Differences in biological maturation and physical fitness between playing positions in youth team handball

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Abstract

It was the goal of this cross-sectional study to examine differences in maturity, anthropometry and physical fitness between youth handball players across different playing positions (i.e. goalkeeper, back, pivot and wing). Multivariate analysis of covariance (MANCOVA), accounting for biological maturation, was used to assess positional differences in 472 male youth handball players from three age groups: U14, U15 and U16. Differences in age at peak height velocity were found in all age groups. Backs were significantly more mature than wings in U14 and U15 and than wings and pivots in U16. Furthermore, backs are overall taller, have a bigger arm span and perform best on tests for strength, agility and speed, especially in the U15 age group. Therefore, it can be concluded that youth players with the most advanced maturation status and the most favourable anthropometry and physical fitness scores, are consistently positioned in the back position. Players with a less advanced maturity status and an overall smaller stature are placed on the wing or pivot positions. In conclusion, it seems that anthropometrical and maturational characteristics are used by coaches to directly and/or indirectly select players for specific field positions. This strategy is risky since anthropometry and maturity status change over the years.

Introduction

Team handball is an Olympic team sport in which body size, strength, speed and agility, in addition to technical skills are considered important factors in successful participation at elite levels (Gorostiaga et al., 2005; Mohamed et al., 2009). Handball is played by six court players (three backs, two wings and one pivot) and a goal- keeper that are required to fulfil specific tasks according to their field position. Profiling players by position has already been studied in a variety of team sports, e.g. rugby league (Gabbet et al., 2008), basketball (Ostojic et al., 2006), Australian football (Pyne et al., 2006), Gaelic football (Cullen et al., 2012), soccer (Coelho e Silva et al., 2010; Rebelo et al., 2012; Stroyer et al., 2004) and handball (Chaouachi et al., 2009; Srhoj et al., 2002; Vila et al., 2012) and revealed that between playing positions, large differences in anthropometry and occur. Several authors have already discussed the importance of anthropometric variables in youth and adult team handball players (Lidor et al., 2005; Matthys et al., 2011; Mohamed et al., 2009; Ziv & Lidor, 2009). However, research on the profiling of biological maturation, anthropometry and physical fitness in youth handball players across playing positions is lacking.

In adult team handball, back players are taller and have a greater body mass compared to wings (Chaouachi et al., 2009), which helps when shooting from distance (van den Tillaar & Ettema, 2004). Since, players positioned on the wing rarely engage in physical contact with the opposing defenders, a tall stature and high body weight are of less impor- tance to successful performance in this position. Pivots play within the opponent's defensive formation with the back or flank facing the goal and the defenders themselves. To perform well on the pivot- position, Sporis et al. (2010) stated that a strong upper part of the body and a relatively large total body mass are needed to engage in physical contact for favourable positions. Finally, the goalkeeper should ideally possess a large stature and relatively long limbs. This helps in covering bigger goal areas and implementing save movements in parts of the goal (Sporis et al., 2010). In conclusion, there appears to be a great difference in the anthropometric characteristics of players playing in different field positions in adult handball (Srhoj et al., 2002).

In team handball, as is the case in most youth sports, male players who are biologically more advanced in maturation are generally taller, heavier, carry greater mass-for-stature and demonstrate superior performance in tasks that require speed, power, and strength (Malina et al., 2004; Matthys et al., 2012; Pearson et al., 2006). However, deliberately selecting players with an advanced maturation status for certain field positions involves risks. Those players advanced in biological maturation and physical fitness in early adolescence may not retain these physical advantages into adulthood (Pearson et al., 2006; Vaeyens et al., 2008). Furthermore, research in youth soccer revealed that when specialisation in one field position occurs too soon, relocation to another position then becomes more difficult due to a loss of tactical and technical skills, even in highly talented players (Stroyer et al., 2004).

In light of our limited understanding of the role that biological maturation may play in relation to the selection and performance of youth handball players, the purpose of this study was to examine differences in anthropometry and physical fitness between different field positions (back, goalkeeper, wing and pivot) in U14, U15 and U16 team handball players. It was anticipated that back players would be the tallest and most mature, while wings would be the smallest, lightest and least mature players.

Methods

Study design and participants

The sample included 472 unique youth handball players aged 13.00 to 15.99 years, of European ancestry, from clubs of different playing levels situated throughout the Flemish region of Belgium. The positions of the players were obtained through a questionnaire in which they noted their primary and, if possible, secondary playing position from the following positions: goalkeeper, wing, back or pivot. The Ethics Committee of the Ghent University Hospital approved this study. Informed parental consent and player assent were obtained. Parents or guardians and players were also informed that participation was voluntary and that they could withdraw at any time. With the estimation method of Sherar et al. (2005), the adult stature can be predicted by using reference values obtained from maturity and sex-specific height velocity curves (Mirwald et al., 2002). By then corresponding the age at peak height velocity (APHV) value calculated with the Mirwald et al. (2002) formula with the predicted adult stature calculated with the Sherar et al. (2005) formula, it was concluded that none of the players in this sample had reached the predicted adult stature, i.e. the fully mature status.

Measurements

The following anthropometric measurements were taken using standardised protocols (Lohman et al., 1988): height (0.1 cm, Holtain, UK), sitting height (0.1 cm, Holtain, UK), body mass (0.1 kg) and body fat percentage (0.1%) with a total body composition analyser (TANITA BC-420SMA, Japan). Arm span (0.1 cm) was assessed with a measuring tape. The same qualified researcher took all anthropometric measures. Sitting height was subtracted from height to estimate leg length (0.1 cm). The technical error of measurement (TEM) with a test-retest period of one hour in 40 adolescents was 0.49 cm for height, 0.47

cm for sitting height and 0.48 cm for arm span.

In order to estimate the maturity status of the handball players, a non-invasive technique based on chronological age (decimal age) and anthropometrical variables, was used (Mirwald et al., 2002). The biological maturation index predicts years from peak height velocity (PHV) as a measure of maturity-offset according to the following equation: –9.236 + 0.0002708 (leg length × sitting height) –0.001663 (age × leg length) + 0.007216 (age × sitting height) + 0.02292 (weight by height ratio), where R = 0.94, R^2 = 0.89, and Standard Error of Estimate (SEE) = 0.59. Length measurements are in centimetres and weight measurements are in kilo- grams, the weight by height ratio is multiplied by 100. Consequently, age at peak height velocity (APHV) was calculated as the difference between chronological age and the predicted years from PHV. For example, among boys of the same chronological age the boy who would achieve predicted peak height velocity two years in advance of another would be considered biologically more mature for his chronological age.

The physical fitness measures consisted of specific tests assessing strength, speed and agility. To assess explosive leg strength, players performed three single counter movement jumps (CMJ) with arm swing (OptoJump, MicroGate, Italy). The highest of the three jumps was used for further analysis (0.1 cm). A

5-jump test for distance (0.01 m) (Chamari et al., 2008) was also executed. A handball specific shuttle run (0.1 s) (Mohamed et al., 2009), which required specific defensive sliding movements, was used to assess sport-specific speed and agility. Players' agility with the ball was measured by the slalom dribble test (0.1 s) (Lidor et al., 2005) and a 10 × 5 m shuttle run test (0.001 s) (Council of Europe, 1988) was used to evaluate speed and agility over a short distance. Finally, players performed two maximal sprints of 20 m (0.001 s) with a split time at 10 m. The fastest sprint was used for analysis. The shuttle run and sprint performances were recorded using MicroGate Racetime2 chronometry and Polifemo Light photocells (MicroGate, Italy).

Data analysis

To examine differences in chronological age and APHV between playing positions, a multivariate analysis of variance (MANOVA) was used. Furthermore, multivariate analyses of covariance (MANCOVA) were used to investigate the positional differences in anthropometry, strength, agility and speed for each age group separately, with maturation accounted for. A Bonferroni correction for multiple comparisons was used to assess differences between the four field positions. All analyses were performed using SPSS 15.0 with the minimal level of significance set at $P < 0.05$.

Results

Tables I, II and III show the results of the MAN(C)OVA analyses used to investigate differences in anthropometric characteristics and physical fitness measures between field positions for the three age groups separately.

Maturation was a significant covariate for all anthropometric characteristics across the three age groups. The following physical fitness measures were significantly affected by maturation: 5-jump test, hand- ball specific shuttle run and sprint 20 m in U14; CMJ, 5-jump test, sprint 10 m and sprint 20 m in U15 and CMJ, 5-jump test, handball specific shuttle run, sprint 10 m and sprint 20 m in U16. For each age group, chronological age was not different between the four playing positions while significant differences in APHV were revealed. The backs had a significant earlier maturity offset com- pared to the wing-position in the U14 and U15 age groups, and compared to the wing and pivot position in the U16 age group.

MANCOVA showed a significant multivariate effect of playing position in measures for anthropometry in the U15 ($F_{(12,424)} = 2.75$; $P = 0.001$; Partial Eta Squared = 0.06) and U16 age groups ($F_{(12,371)} = 2.31$; $P = 0.007$; Partial Eta Squared = 0.06). Except arm span and height in U14, significant univariate between-group differences were found for all anthropometric variables in all age groups. Backs and goalkeepers were generally taller and had a longer arm span compared to pivots and wings. The lowest weight was observed in wing-players.

MANCOVA revealed significant multivariate differences for strength (F (6,288) = 2.33; P = 0.033; Partial Eta Squared = 0.05), agility (F (9,346) = 2.20; P = 0.022; Partial Eta Squared = 0.04) and speed (F (6,286) = 2.26; P = 0.038; Partial Eta Squared = 0.05) in U14 handball players. For the U15 group, significant multivariate effects of playing position were found on strength (F (6,321) = 2.81; P = 0.011; Partial Eta Squared = 0.05) and agility (F (9,373) = 2.02; P = 0.036; Partial Eta Squared = 0.04), but not on speed (F (6,302) = 1.31; P = 0.252; Partial Eta Squared = 0.03) items. Strength (F (6,270) = 1.35; P = 0.235; Partial Eta Squared = 0.03), agility (F (9,326) = 0.39; P = 0.942; Partial Eta Squared = 0.01) and speed (F (6,264) = 1.18; P = 0.320; Partial eta Squared = 0.03) were not different between playing positions on a multivariate level in the U16 age group. Subsequent univariate analyses showed that all of the strength-items in the three age groups were significantly different between the playing positions, except for the 5-jump test. Back players jumped higher and further compared to the other positions. Significant univariate differences between field positions were also observed for agility in U14 and U15. More specifically, differences were found for the shuttle run and slalom dribble test in U14; for the shuttle run, handball specific shuttle run and slalom dribble test in U15. Except for the handball specific shuttle run in U14, the back players showed the best results for agility over the three age groups. In U14, significant univariate effects of field position were found on the speed-items in favour of the back-players, while no univariate differences between the playing positions were revealed in U15 and U16.

Table I. Anthropometry and physical performance of U14 handball players by playing position.

		Positions				Covariate	ANCOVA			
		Back $n = 49$	Goalkeeper $n = 20$	Pivot $n = 18$	Wing $n = 68$	Maturation	df	Effect size	F	P
	Chronological age (years)	13.5 ± 0.3	13.5 ± 0.3	13.5 ± 0.3	13.4 ± 0.3	-	3,150	0.03	1.339	0.264
	APHV (years)	13.6 ± 0.6^{a}	13.8 ± 0.6^{a,b}	13.8 ± 0.5^{a}	14.1 ± 0.6^{b}	-	3,150	0.12	6.863	<0.001
Anthropometry										
	Height (cm)	167.7 ± 7.2	164.0 ± 8.7	164.0 ± 7.8	159.5 ± 7.7	***	3,150	0.04	2.143	0.097
	Weight (kg)	53.8 ± 9.7^{a}	51.4 ± 10.9^{a}	57.8 ± 10.2^{b}	47.4 ± 10.1^{a}	***	3,150	0.08	4.318	0.006
	Body fat (%)	12.0 ± 5.1^{a}	11.8 ± 4.2^{a}	17.5 ± 7.7^{b}	12.4 ± 5.5^{a}	*	3,150	0.09	5.104	0.002
	Arm span (cm)	170.0 ± 9.1	166.2 ± 9.8	166.1 ± 7.9	160.8 ± 9.2	***	3,150	0.03	1.641	0.182
Strength										
	CMJ (cm)	33.3 ± 5.7^{a}	30.6 ± 4.9^{a,b}	28.9 ± 5.2^{b}	31.3 ± 5.4^{a,b}	n.s.	3,145	0.06	2.868	0.039
	5-jump test (m)	10.6 ± 1.8^{a}	9.6 ± 1.1 ^{b}	9.4 ± 0.8^{b}	9.8 ± 0.9^{b}	**	3,145	0.09	4.480	0.005
Agility										
	Shuttle run (s)	18.15 ± 1.13^{a}	18.80 ± 1.31^{a,b}	19.23 ± 1.31^{b}	18.88 ± 1.28^{b}	n.s.	3,144	0.08	3.910	0.010
	Handball specific shuttle run (s)	13.7 ± 1.5	14.6 ± 1.9	13.5 ± 3.7	14.5 ± 1.6	*	3,144	0.03	1.351	0.260
	Slalom dribble test (s)	8.9 ± 0.8^{a}	9.9 ± 1.6^{b}	9.0 ± 2.9^{a,b}	9.7 ± 1.2 ^{b}	n.s.	3,144	0.05	2.685	0.049
Speed										
	Sprint 10 m (s)	2.02 ± 0.14^{a}	2.13 ± 0.16^{b}	2.14 ± 0.16b	2.09 ± 0.13^{a,b}	n.s.	3,144	0.07	3.773	0.012
	Sprint 20 m (s)	3.51 ± 0.26^{a}	3.72 ± 0.30^{b}	3.73 ± 0.25^{b}	3.63 ± 0.24^{a,b}	n.s.	3,144	0.08	4.330	0.006

Note: Data are means ± standard deviations; n.s. = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
Means in the same row having the same superscript are not significantly different.

Table II. Anthropometry and physical performance of U15 handball players by playing position.

		Positions				Covariate	ANCOVA			
		Back *n* = 79	Goalkeeper *n* = 27	Pivot *n* = 22	Wing *n* = 40	Maturation	df	Effect size	*F*	*P*
	Chronological age (years)	14.5 ± 0.3	14.5 ± 0.3	14.5 ± 0.3	14.5 ± 0.3	-	3,163	0.01	0.299	0.826
	APHV (years)	13.7 ± 0.6^{a}	13.6 ± 0.6^{a}	13.8 ± 0.6^{a,b}	14.2 ± 0.7^{b}	-	3,163	0.09	5.267	0.002
Anthropometry										
	Height (cm)	173.0 ± 7.7^{a}	173.7 ± 7.1^{a}	170.0 ± 6.5^{a,b}	166.7 ± 7.9^{b}	***	3,163	0.03	3.132	0.027
	Weight (kg)	59.6 ± 9.7^{a}	63.8 ± 12.0^{b}	61.9 ± 10.3^{b}	52.4 ± 9.2^{c}	***	3,163	0.09	6.272	<0.001
	Body fat (%)	11.6 ± 3.6^{a}	13.3 ± 5.5^{a,b}	14.3 ± 4.8^{b}	10.3 ± 4.5^{a}	**	3,163	0.08	4.324	0.006
	Arm span (cm)	175.8 ± 8.5^{a}	175.2 ± 8.4^{a,b}	173.1 ± 7.7^{a,b}	168.3 ± 8.4^{b}	***	3,163	0.03	2.952	0.034
Strength										
	CMJ (cm)	35.7 ± 4.5	33.5 ± 4.9	33.3 ± 5.4	34.9 ± 5.6	***	3,157	0.04	2.386	0.071
	5-jump test (m)	11.0 ± 0.9^{a}	10.6 ± 1.0^{a,b}	10.1 ± 0.9^{a,b}	10.4 ± 1.0^{b}	***	3,157	0.08	4.377	0.005
Agility										
	Shuttle run (s)	17.75 ± 0.94^{a}	18.36 ± 0.96^{b}	18.48 ± 1.15^{b}	18.41 ± 1.16^{b}	n.s.	3,155	0.08	4.539	0.004
	Handball specific shuttle run (s)	13.2 ± 1.1	13.8 ± 1.2	13.7 ± 1.5	13.8 ± 1.3	n.s.	3,155	0.04	2.291	0.080
	Slalom dribble test (s)	8.6 ± 0.8^{a}	9.2 ± 1.0^{b}	9.0 ± 1.0^{a,b}	9.2 ± 1.2^{b}	n.s.	3,155	0.01	4.127	0.008
Speed										
	Sprint 10 m (s)	1.97 ± 0.11	2.02 ± 0.11	2.04 ± 0.14	2.01 ± 0.11	***	3,152	0.05	2.368	0.073
	Sprint 20 m (s)	3.40 ± 0.19	3.47 ± 0.31	3.51 ± 0.26	3.46 ± 0.21	***	3,152	0.03	1.649	0.180

Note: Data are means ± standard deviations; n.s. = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
Means in the same row having the same superscript are not significantly different.

Table III. Anthropometry and physical performance of U16 handball players by playing position.

		Positions				Covariate	ANCOVA			
		Back $n = 55$	Goalkeeper $n = 27$	Pivot $n = 20$	Wing $n = 46$	Maturation	df	Effect size	F	P
	Chronological age (years)	15.5 ± 0.2	15.5 ± 0.3	15.5 ± 0.3	15.4 ± 0.2	–	3,146	0.02	0.724	0.539
	APHV (years)	13.7 ± 0.6^{a}	13.5 ± 0.6^{a}	14.0 ± 0.7^{b}	14.1 ± 0.6^{b}	–	3,146	0.14	8.116	<0.001
Anthropometry										
	Height (cm)	178.3 ± 6.9^{a}	180.5 ± 5.9^{a}	172.9 ± 6.3^{b}	173.6 ± 7.3^{a}	***	3,143	0.07	4.624	0.004
	Weight (kg)	65.2 ± 8.6^{a,b}	68.4 ± 8.7^{a}	65.2 ± 8.9^{a}	58.8 ± 7.4^{b}	***	3,143	0.10	3.330	0.021
	Body fat (%)	11.3 ± 4.0^{a}	11.4 ± 4.1^{a}	13.4 ± 4.7^{b}	9.9 ± 3.1^{a}	*	3,143	0.08	3.448	0.018
	Arm span (cm)	181.1 ± 8.3	183.4 ± 7.3	175.4 ± 7.7	176.3 ± 7.7	***	3,143	0.06	2.647	0.049
Strength										
	CMJ (cm)	38.9 ± 4.3	36.5 ± 4.1	38.8 ± 4.9	37.5 ± 4.3	**	3,136	0.05	2.465	0.065
	5-jump test (m)	11.3 ± 1.8	11.3 ± 0.7	11.2 ± 1.0	11.0 ± 0.9	**	3,136	0.00	0.028	0.994
Agility										
	Shuttle run (s)	17.31 ± 1.1	17.67 ± 1.15	17.53 ±0.91	17.68 ± 1.15	n.s.	3,136	0.02	0.855	0.466
	Handball specific shuttle run (s)	12.4 ± 1.1	12.8 ± 1.1	12.5 ± 1.2	12.9 ± 2.3	*	3,136	0.01	0.662	0.577
	Slalom dribble test (s)	8.4 ± 0.9	8.6 ± 0.8	8.5 ± 0.6	8.7 ± 1.7	n.s.	3,136	0.01	0.313	0.816
Speed										
	Sprint 10 m (s)	1.93 ± 0.22	1.93 ± 0.09	1.89 ± 0.09	1.97 ± 0.17	**	3,133	0.01	0.487	0.692
	Sprint 20 m (s)	3.25 ± 0.16^{a,b}	3.33 ± 0.12^{a}	3.24 ± 0.27^{b}	3.35 ± 0.20^{a,b}	***	3,133	0.04	0.973	0.121

Note: Data are means ± standard deviations; n.s. = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$
Means in the same row having the same superscript are not significantly different.

Discussion

It was in the interest of this study to examine differences in anthropometry and physical fitness between different field positions in U14, U15 and U16 male team handball players. The present data suggest that there is a consistent difference in biological maturation between back and wing players from the U14–U16 age groups. Furthermore, it seems that back players have overall beneficial anthropometric values and possess the best physical fitness measures, especially in the U15 category.

The non-invasive estimate of maturity status by Mirwald et al. (2002) has some limitations. It has not been externally validated on an independent longitudinal sample of athletes for which APHV is known or with other established maturity indicators during adolescence (i.e. skeletal age, secondary sex characteristics). However Mirwald et al. (2002) reported a correlation coefficient of 0.83 between skeletal age- offset and PHV maturity-offset based on a longitudinal sample of Canadian schoolchildren. Therefore, application to individual athletes needs to be made with care. In contrast with the used method, other methods for assessing maturity can be expensive (i.e. wrist radiographs), intrusive (i.e. the assessment of sexual maturity), unethical (i.e. longitudinal assessment of RX-radiographs) or require longitudinal observations. Predicted APHV based on maturity- offset shows relatively small standard deviations, especially in small children such as female gymnasts (Baxter-Jones et al., 2003). Therefore, this technique has proven to be valuable, but the usability has to be considered per population.

Large anthropometric dimensions have been proven to have a positive effect on youth and adult team handball players' performance (Lidor et al., 2005; Mohamed et al., 2009; Ziv, & Lidor, 2009). The present study shows that back-players and goal- keepers are the tallest players on the team, with the largest arm span. On the other hand, pivots and the wings are the smallest players and pivots have the highest percentage body fat. These position-specific anthropometric characteristics of youth handball players correspond well with the anthropometric characteristics observed in adult players (Chaouachi et al., 2009; Sporis et al., 2010; Srhoj et al., 2002). It could therefore be concluded that the selection criteria used to select players for certain field positions in youth handball shows similarities with the differences observed between playing positions in adult handball. However, it should be recognized that the impact of biological maturation on the selection process in sport might be direct or indirect in nature (Bloom, 1985; Cumming et al., 2012). In a recent review of theory and research pertaining to biological maturity and physical activity in adolescence, Cumming et al. (2012) argued that the impact of biological maturation on athlete selection is complex. Whereas biological maturation may directly influence athlete selection through variance in physical size, capacity, and performance, it may also exert indirect effects. There is compelling evidence to suggest that the physical and functional changes associated with variance in biological maturation hold stimulus value for the athlete and for significant others (e.g. peers, parents, and coaches) ultimately affecting the manner in which athletes perceive themselves, and the manner in which they are perceived and treated by others. Accordingly, athletes with the physical characteristics most appropriate for success in their sports would be expected to hold higher perceptions of competence, and experience a psychosocial environment that was more supportive and conductive to their further development (Sherar et al., 2010). For example, gymnasts who are shorter, lighter, and carry less mass for stature perceive their coaches to react more favourably (i.e. greater encouragement and instruction, and less punishment, irrespective of ability or performance) (Cumming et al., 2006). Future research should seek to differentiate between the direct and indirect effects of bio- logical maturation on maturity and growth based selection processes in sports through the integration of physical and psychosocial constructs and measures (e.g. psychological profiling, motivation, etc.).

Additionally, the present results show that there are significant differences between playing positions in U14 and U15 regarding strength, speed and agility. However, in U16 no significant differences between playing positions were revealed. This is somewhat surprising because position-specific specialisation was expected to be most pronounced in the eldest age group. Since team handball is played indoors on a small court, handball players may be more homogeneous from a physical point of view compared to big playing-field sports, such as rugby, Australian football and soccer (Chaouachi et al., 2009). Consequently, selection in older age categories might be even more focused on anthropometric characteristics and maturity status instead of on physical fitness. However, a maturity-based selection for playing positions holds a risk, because the effect of growth and maturation might interfere with these young players' development (Pearson et al., 2006). Indeed, other studies have shown that, following puberty; late maturing boys can catch up with or even surpass their early and on- time maturing counterparts in anthropometric characteristics and physical fitness (Beunen et al., 1997; Pearson et al., 2006).

Recommendations

Coaches and training professionals in youth team handball should be aware of the maturity-based selection of young handball players for different playing positions. These differences between players are likely to change throughout puberty and maturity- based selection is therefore not recommended in youth handball. It must be stipulated however that the trend in youth sports nowadays is not the long- term development of outstanding athletes, but the short-term development of outstanding performances. It is therefore not surprising that some coaches prefer short-term performance to long-term development, thus further stimulating the selection of youth players for certain playing positions based on maturity status. A broad athletic development, followed by a higher degree of handball-specific and position a-specific training and finally a specialisation per position might be an approach worth investigating further.

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STUDY 6:

Differences in anthropometry and physical fitness between back and forward rugby union players post age at peak height velocity

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Unsubmitted work

Abstract

The goal of this cross-sectional study was to examine differences in anthropometry and physical fitness between playing positions in youth rugby union. Multivariate analysis of variance (MANOVA) was used to assess anthropometry, physical fitness and motor competence tests for back and forward players aged 16.2 ± 2.0 years from a school rugby program. Within this age group, differences in anthropometry and physical fitness were found between playing positions ($F = 2.567$, $p = 0.009$, effect size = .53). Forwards were heavier and possessed a higher BMI than backs, while backs had better scores on standing broad jump, vertical jump and 20 and 30m sprint. It is apparent that this particular cohort of youth rugby players has been selected into positions based on the physical requirements of professional rugby players, such as body size for forwards, and speed and functional, explosive strength for backs. This selection strategy used by coaches may narrow down player profiles before physical and psychological maturation, and may possibly result in an early specialisation that is detrimental to overall athletic and rugby specific development.

Introduction

Rugby union is an international, field-based team sport, involving intermittent bouts of high-intensity activity including frequent physical collisions (Duthie et al. 2003). Optimal rugby performance therefore requires players to possess highly developed speed, agility, strength, and power characteristics (Duthie 2006). However, the physical characteristics and physical match demands of adult rugby players are vastly different between playing positions. Differences between playing positions have recently been studied in a variety of team sports such as team handball (Mathys et al., 2013; Vila et al., 2012), rugby league (Gabett et al., 2008), Australian football (Pyne et al., 2006), soccer (Coelho e Silva et al., 2010; Rebelo et al., 2012), Gaelic football (Cullen et al., 2012) and rugby union (Duthie et al, 2003; Duthie, 2006). In professional rugby union, backs tend to be leaner, shorter, faster, and more explosive and run further during matches when compared to forwards. On the other hand, forwards have been shown to possess greater absolute power and take part in considerably more high-intensity activity and collisions during a match (Duthie et al. 2003).

With this knowledge, a coach may be inclined to use physical characteristics such as these to select players for specific field positions. Matthys and colleagues (2013) argued that selection for youth team handball field positions was largely maturity based. Back players in youth team handball had a significantly earlier maturity offset, were significantly taller and had longer arm spans than wing players. This 'favourable' anthropometry allows back players to better execute position specific tasks during games such as shooting over the defensive line and blocking opposition shots at goal. However, this research group argued that these players may not retain physical attributes into adulthood (Pearson et al., 2006) and therefore early position-specific specialisation based on physical characteristics is not ideal (Matthys et al., 2013). In a study on the development of position-specific indicators for youth rugby league, Cupples and O'Connor (2006) identified a specific set of variables that were considered important for successful participation in rugby league by experienced coaches. This implies that at a youth rugby level, coaches recognize that differences between field positions are present. However, position specific differences in anthropometry and physical fitness in youth rugby union have not yet been investigated.

Therefore, this study aimed to examine differences in anthropometry and physical fitness between backs and forwards in youth rugby union. It was hypothesised that, in accordance with player profiles in adult rugby, backs and forwards would possess different profiles in youth rugby. We hypothesise that backs have a lower body mass and Body Mass Index (BMI), possess more explosive strength and faster sprint speed than forward players. Furthermore, we expect forward players to demonstrate a higher absolute strength than back players.

Methods

Study Design and Participants

Seventy-nine male rugby union players aged 16.2 ± 2.0 years, from the same high school rugby union program participated in this cross-sectional study. Anthropometry, physical fitness and motor competence were profiled in 21 backs and 32 forwards based on coach-reported field positions. The hooker, prop, lock, number eight and flanker positions were labelled as forwards, the scrum-half, fly-half, centre, wing and full back positions were labelled as backs. Twenty-six players dropped out of the study due to not completing one or more tests because of injury or absence on the day of testing. A written consent form was obtained from each subject prior to the commencement of this study. Before any testing, ethical approval was granted by an Institutional Human Research Ethics Committee.

Measurements

Stature and body mass were measured according to protocol (Malina, Bouchard and Bar-or, 2004). Stature was measured to the nearest 0.1cm using a wall-mounted stadiometer and body mass was assessed using digital weighing scales (Universal Weight Enterprise, Taiwan). Body mass and stature were used to calculate the BMI to determine stature/weight ratios. To determine if all participants were post Age at Peak Height Velocity (APHV), biological maturation was estimated using anthropometrical measures of stature, body mass and leg length according to the guidelines by Mirwald et al. (2002). APHV in the test sample in this study was on average 13.5±0.5 and players were on average 3.0±1.0 years post-APHV. All players in this study were characterised as being post APHV. Explosive strength in a horizontal was measured using the EUROFIT (Council of Europe, 1988) Standing Broad Jump. Jump height as a measure of explosive strength in a vertical plane was measured by a modified version of the Sargent Reach and Jump test (Sargant, 1921) using a yardstick apparatus (Swift Performance Equipment, Australia). Absolute power tests were measured by a 3kg medicine ball power pass (chest throw from upright position), caber toss (underhand throw from upright position) and overhead throw (backward overhead throw from upright position). These tests have been used in previous studies (Stockbrugger et al., 2001; 2003) and are frequently used for performance assessment in this rugby program. Dual beam timing gates (Swift Performance Equipment, Australia) were used to assess speed over 5m, 20m and 30m intervals. Motor competence was assessed using three KTK subtests: 1) Jumping Sideways; 2)

Moving Sideways; 3) Balancing Backwards. The raw scores on these three tests separately were used as was previously done by Vandendriessche et al. (2012) in youth soccer players. For an elaborate description of these tests, please consult Kiphard and Schilling (1974). The YoYo Intermittent Recovery Test Level 1 (YoYo IR1) was used to assess rugby-specific cardiovascular endurance. This test was assessed according to protocol (Bangsbo et al., 2008) and the total distance covered in metres was the final output measure used.

Data Analysis

Univariate analysis of variance (ANOVA) was used to analyse potential confounding differences in chronological age between backs and forwards in this study. Multivariate Analysis of Variance (MANOVA) was used to assess differences in anthropometry and physical fitness characteristics between backs and forwards. Anthropometry and physical fitness variables were the dependent variables and field position (back or forward) was a fixed factor.

Results

Means ± F-values, P-values and effect sizes for the MANOVA can be found in Table 1. MANOVA did not show significant differences in chronological age between backs and forwards in this study ($F = 0.118$, $p = 0.732$, effect size = .00). MANOVA showed a multivariate effect of field position on anthropometry, physical fitness and motor competence ($F = 2.567$, $p = 0.009$, effect size = .53).

A univariate effect of playing position on measures of anthropometry was found for body mass and BMI. Forwards were significantly heavier and had a larger BMI than back players. On measures of strength and power, back players performed better than forwards on the vertical jump and standing broad jump tests. Furthermore, back players were significantly faster than forwards over both 20 and 30 m. There were no significant differences in tests for motor competence and YoYo IR1 distance between backs and forwards. However, jumping sideways and YoYo IR1 did show a trend towards a significant difference between field positions in this study with a fairly small effect size of .04 and .06 respectively.

Table 1: MANOVA for differences between back and forward players in youth rugby union

	Positions				
	Forwards	**Backs**	**Effect size**	**F**	***P***
	n = 32	*n = 21*			
Chronological Age (y)	16.4 ±1.0	16.3 ±1.2	.00	0.118	0.732
Anthropometry					
Stature (cm)	179.9 ±7.2	178.4 ±6.9	.01	0.534	0.468
Body Mass (kg)	82.9 ±11.4	73.2 ±10.7	.16	9.538	0.003
Body Mass Index (kg/m^2)	25.6 ±2.7	22.9 ±2.2	.22	14.516	0.000
Strength/Power					
Vertical Jump (cm)	52.1 ±7.0	57.3 ±6.6	.13	7.486	0.001
Standing Broad Jump (cm)	222.0 ±20.2	236.7 ±15.6	.14	7.967	0.007
Overhead Throw (m)	12.5 ±2.3	12.1 ±2.2	.01	0.546	0.463
Caber Toss (m)	12.3 ±2.2	12.5 ±1.9	.00	0.192	0.663
Power Pass (m)	7.2 ±1.0	6.9 ±0.9	.03	1.304	0.259
Flexibility					
Sit and Reach (cm)	7.1 ±10.5	7.1 ±4.9	.00	0.000	0.994
Speed					
5 m Sprint (s)	1.10 ±0.07	1.06 ±0.07	.07	3.632	0.062
20 m Sprint (s)	3.26 ±0.18	3.11 ±0.16	.16	9.509	0.003
30 m Sprint (s)	4.55 ±0.32	4.35 ±0.24	.10	5.948	0.018
Motor Competence					
Moving Sideways	61 ±7	65 ±9	.04	2.138	0.150
Jumping Sideways	91 ±11	96 ±7	.07	3.569	0.065
Balance Beam	57 ±10	57 ±12	.00	0.019	0.890
Endurance					
Yo-Yo IR1 Distance (m)	1573 ±564	1836 ±399	.06	3.444	0.063

Note: Data are means ± standard deviations

Discussion

The findings of this cross-sectional study showed that forward players were heavier and had a higher BMI, while back players possessed greater speed and explosive strength. Despite this being the first study to investigate the physical profile of youth rugby union players, similar findings have been reported in professional rugby union (Duthie et al., 2003). Duthie et al. (2003) showed that forwards possessed greater absolute strength than back players. However, this was not apparent in the present study. Backs and forwards did not show different performances on caber toss, overhead throw or power pass tests. It is apparent that this particular cohort of youth rugby players has been selected into positions based on the physical requirements of professional rugby players with one exception. While speed and power are important attributes for backs, only body weight and height/weight ratio (BMI), and not absolute strength were the most important attributes for forwards. It can thus be concluded that favourable body dimensions (height and weight) is the most important attribute for forward players in youth rugby union.

However, anthropometry and physical fitness are heavily dependent on biological maturity (Philippaerts et al. 2006), and therefore adolescents may not retain these physical characteristics into adulthood (Pearson et al., 2006). Because of the differences between player profiles for different positions in adult rugby union (Duthie, 2003), early selection for a specific field position might narrow player profiles. Therefore, players who train specifically for certain field positions may find it hard to transfer their skills to another field position in the future (Stroyer et al., 2004) once physical maturation is fulfilled (Matthys et al., 2013).

In conclusion, this study was the first to examine positions-specific differences in anthropometry and physical fitness in youth rugby players post APHV. An observation of 53 players aged 16.2 ± 2.0 years from a high school rugby program demonstrated that back players possess superior physical fitness than forwards, especially on explosive strength and 20 m and 30 m sprint time. However, the limitations of this study included the inability to measure and analyse biological maturity in this group of players, not including a valid measure of body composition in adolescent athletes such as skinfold measurements, and subdividing players into only two field positions. Therefore, we suggest that further research should investigate position specific differences between a broad range of field positions in youth rugby, with a particular emphasis on including a measurement for biological maturity.

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PART 4: GENERAL DISCUSSION

A. Conclusions and contributions to general knowledge

1) Measuring motor competence

Measuring motor competence using the KTK (Kiphard and Schilling, 1974) has been proven to be reliable and valid in previous research. Furthermore, the KTK has been shown to discriminate between elite and sub-elite female gymnasts, implying that it might be a valuable instrument to be used for talent identification research. It was hypothesized that, since KTK and BOT-2 Short Form aim to measure the same construct, convergent validity between these batteries would be moderate to good. However, when assessing convergent and discriminant validity between the KTK and another popular testing battery for motor competence in the research presented in this dissertation, correlations and the level of agreement between KTK and the BOT-2 Short Form were weak to moderate. This might be due to the fact that KTK and BOT-2 Short Form, although aiming to measure the same construct, show large differences in content and use different normative data for standardisation of test scores. For example, BOT-2 Short Form measures both fine and gross motor skills, while KTK only measures gross motor skills. Also, the normative sample for the KTK consists of German youths from 1974, while the BOT-2 Short Form uses American youngsters from 2004-2005. As concluded by Smits-Engelsman et al. (1998) who investigated the association between the M-ABC and KTK, no motor competence testing battery can be considered totally valid, until its results can be compared to those of a 'golden standard' testing battery that unfortunately does not yet exist. Therefore, any results from motor assessment batteries currently in use need to be considered battery-specific. Furthermore, researchers using these batteries in clinical and sports setting should be aware of the risk of generalization, as a motor competence battery might potentially incorrectly classify children according to their test results. However, as shown in this doctoral thesis, the use of the KTK has clear practical advantages: it is short and easy to administer, has been found to be reliable and valid and can be used in a general population of children including highly skilled athletes and children with motor development problems from a broad age range, despite its suggested oversensitivity to motor impairment (Smits-Engelsman et al., 1998). Furthermore, because of the fact that the KTK uses the same test items throughout, it can easily be used for follow-up studies and it takes little time to educate test administrators on how to conduct each test. Therefore, it can be concluded that the KTK has the potential to be an indispensable item when profiling motor competence in children for different purposes. However the use of an additional motor competence assessment instrument, especially when attempting to identify motor problems, might be advisable.

2) Developing motor competence

Practical models aimed at developing motor skills and/or athletic ability (e.g. Long Term Athlete Development Program by Balyi & Hamilton, 2004) believe that motor skill development is particularly sensitive at certain developmental stages in children. This particular model even states that between 9-12 years, this window is critical for optimal athletic development. However, hardly any empirical evidence has supported this 'windows of opportunity' hypothesis (Ford et al., 2011). Earlier research by Hirtz (1977) showed that peak development in time perception, simple motor reactions and the ability to differentiate peaks between the ages 10-14 years while spatial orientation and perception continue to develop afterwards. Furthermore, this research showed that balance, reaction time, rhythm and jumping coordination were also particularly sensitive to change before the age of 12 years. If general motor competence is particularly sensitive to change during childhood, this holds important implications for programs aimed at remediating motor difficulties or maximizing athletic performance. The research in this doctorate shows that, within a group of Flemish elementary school children, there is indeed reason to believe that motor competence is sensitive to change before the age of 12 years. Children older than 11 years seemed to be unable to further develop their motor skill proficiency to exceed those two years prior. Hence, it might be of importance to implement rehabilitation programs for children at risk of having poor motor competence as well as talent development programs aimed at maximizing motor skill development before the age of twelve years.

Children with motor difficulties also have compromised physical fitness levels (Hands, 2008), which might in turn might prevent them from participating in sports and/or physical activity (Stodden et al., 2009). This might then 'snowball' into long-term inactivity with possible detrimental effects on health. Research has shown that children with motor difficulties are indeed at risk. However, studies in more general populations have been scarce. This thesis demonstrated that children from a general population with a relatively low motor competence, as opposed to children with an average or high motor competence have persistently poorer scores on physical fitness tests. These findings are in accordance with the hypothesis in the objectives of the dissertation and could imply that children with a low motor competence and low physical fitness levels at a young age are very much at risk of having a lower motor competence and low physical fitness throughout childhood. As hypothesised by Stodden et al. (2009), this might hinder their participation in organized sports and physical activity. The current study showed that indeed, these children do not participate as often in organized sports as their average and high motor competence peers. Over time, children with a low and high motor competence showed no differences in changes in physical fitness. This means that although children who possess a relatively low motor competence also possess relatively low physical fitness levels in comparison with their peers, the situation does not seem to deteriorate rapidly. We had expected that the difference in physical fitness between motor competence groups would not disappear over time, but it is somewhat surprising that there was no increase in physical fitness differences over time. However, a catch-up effect was not apparent either, making this persistent deficit in physical fitness a possible long-term situation.

3) Early diversification versus early specialisation

Two major pathways to expertise have dominated research on talent identification and development. One pathway favours early specialisation in a single domain while the other pathway proposes a delayed specialisation stage when children reach sufficient biological, psychologial and physiological maturation to start highly specific training (Côté et al., 2009). During the first stage of athletic development, the latter proposes a combination of deliberate play and the sampling of different sports. This might help to create a broad basis of fundamental skills needed to progress to specialised training in one domain. It is in the interest of sports institutions and governing bodies worldwide to understand the effects of both pathways on the development of successful sports involvement. Therefore this thesis investigated the effect of sampling or specialising on measures of motor competence and physical fitness. This research showed that relatively older (10-12 years) boys sampling different sports have better measures of physical fitness and motor competence than those children that specialise in just one sport. Since the effect of sampling seems to only be apparent in the oldest age group, these findings met our expectations of a possible latency of this 'sampling effect'. Although this study does not provide empirical evidence for the superiority of the early diversification over the early specialisation pathway in any way, it does seem to add to the notion that sampling more than one sport does not per se hinder performance (Côté et al., 2009).

When the diversification pathway to expertise is applied to youth sports, there are two outcomes for children that passed through the sampling stage. In the first, talented athletes enter into more specific training programs that require a high degree of athlete investment and are destined to result in expert performance. The second pathway is an extension of the sampling stage aimed at developing a lifelong affinity with sports for those children who do not show exceptional talent. This particular pathway ideally results in life long sports participation and involvement. According to the Developmental Model of Sports Participation (Côté et al., 1999; Côté et al., 2007) and long-time experts in the field of athletic training (Bompa & Haff, 2009), this pathway requires increasing amounts of specialised training while still providing some kind of diversification in the form of a summer/winter sport, general athletic development through for example strength training or delaying position-specific training in favour a more generalized yet sport-specific development. However, how highly specific training at this stage of athletic development might influence the development of future sports involvement, has not yet been investigated. It was therefore in the scope of this thesis to reveal the current state-of-mind concerning position-specific specialisation and the risks this may hold for the future development of handball and rugby union players. We expected that performance profiles for different field positions in youth handball and rugby union would be significantly different. In this dissertation, this hypothesis has been confirmed, as it is clear that youth handball players and rugby union players playing on different field positions have different physical fitness, anthropometry and motor competence profiles. Furthermore, these profiles closely relate to the differences observed between field positions in adult handball and rugby union. For the youth player involved, this might hold serious consequences. Many of the youth players in these two studies, instead of possessing a broad athletic profile so it might suit more than one playing position, now possess a very narrow athletic profile that suits only one position. Having a broad array of skills and well-developed speed, agility, strength, flexibility, motor competence and cardiovascular endurance that suits any field position maximizes the chance of progressing to adult team handball, since it allows a player to quickly fill any open spot on the team and maximizes exposure to high level handball or rugby. Therefore, a young player who is proficient at playing one field position only might reduce his chances of a continued progression considerably as the transfer to another playing position in due time might become increasingly difficult with age and increased skill levels.

4) Towards a new model for the development of successful sports involvement in children and adolescents

Based on these findings, the model used as a framework for this dissertation should be slightly adapted to incorporate an increased emphasis on (perceived) motor competence at a young age in order to be able to sample different activities throughout childhood, a gradual decrease in sampling over time and the possibility to drop out from the expertise pathway at any time that would eventually lead to successful sports involvement for any child (Figure 5).

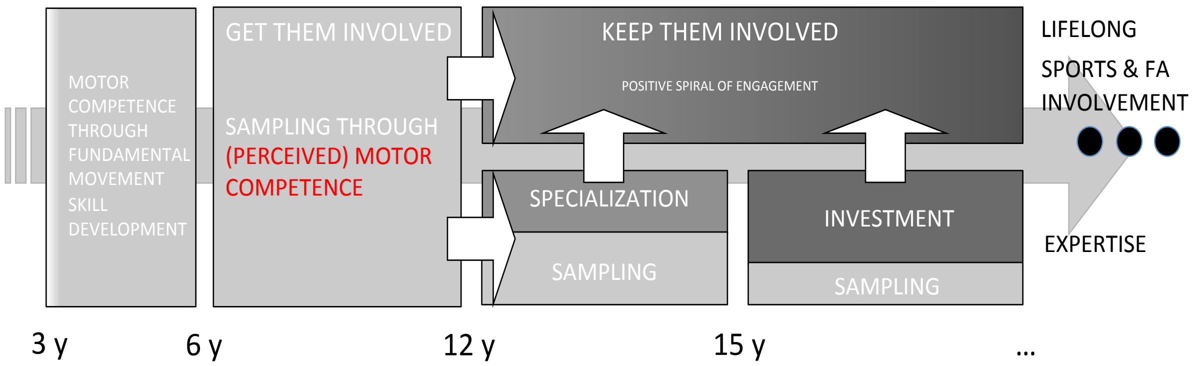

Figure 5: An adapted version of the model for the development of successful sports involvement that incorporates a focus on (perceived) motor competence, gradual specialisation, and possibilities for drop out in each developmental stage.

Fundamental movement skills stage

Although it was not in the scope of this dissertation to elaborate on this particular stage, the focus on fundamental movement skills before the age of 6 years is undoubtedly paramount for future sports involvement. At this age, exposure to different kinds of fundamental movement skills might determine future proficiency in physical activity and sports later on.

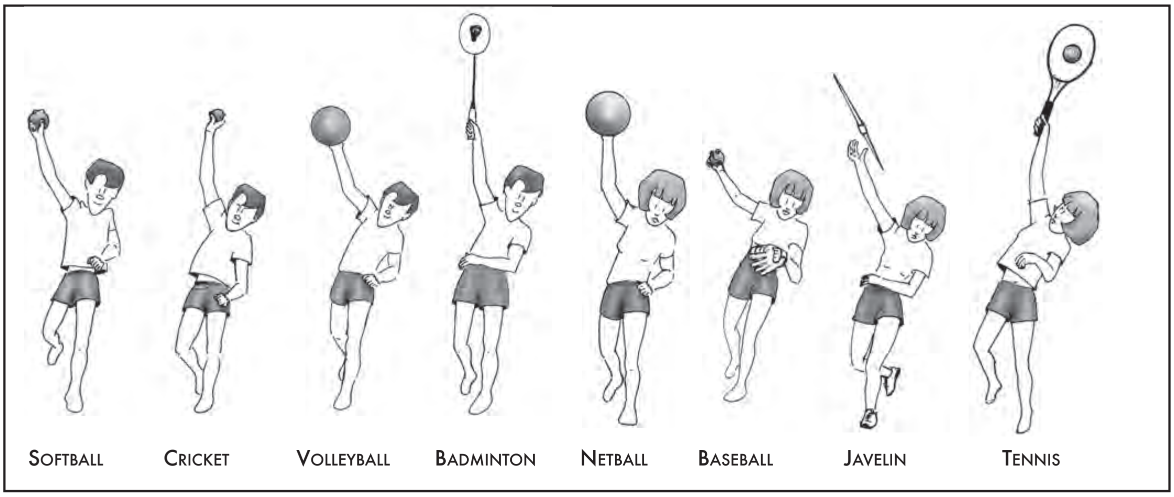

Figure 6: The overarm throw is a fundamental movement skill for future sport-specific skill development from 'Fundamental Motor Skills, a manual for classroom teachers' (Department of education, Victoria, Australia, 1996)

'*Get them involved*'

Based on the conclusions in this dissertation, the 'Get them involved' stage of the model should emphasize motor competence. Research in this age group has demonstrated that interventions aimed at improving motor skill proficiency at this age can be successful. In a paper on the effectiveness of the 'Move it, groove it' program by Van Beurden and colleagues (2003), it was shown that a one-year intervention aimed at improving motor competence had effectively improved results on physical fitness and motor competence tests in an intervention as opposed to a control group. Not only actual motor competence but also perceived motor competence is of particular importance in this stage. Stodden and colleagues (2008) hypothesized that perceived motor competence is an important factor mediating the relationship between motor competence and physical fitness. More-skilled children, especially in late childhood, have higher levels of perceived motor competence and consequently engage in and enjoy physical activity more often. It is thus important to emphasize perceived motor competence as well as actual motor competence in the 'Get them involved' stage.

'Keep them involved'

In the adapted 'Keep them involved' stage of the model, two major changes have been made. First of all, as it was the aim of our model to be applicable in a general population of children, the possibilities for drop out from the performance development pathway at any time are emphasized through the upward arrows in the model. Furthermore, as was mentioned previously, a model for the development of sports involvement should ideally include a gradual increase in specialised training from the age of 12 years on rather than an immediate switch to a sole focus on specialised training.

B. Practical implications

The research in this thesis investigated the pathways leading to successful sports with a particular focus on motor competence and the early diversification versus early specialisation debate. Furthermore, the adaptations to the original framework presented in the introduction may lead to a stronger understanding of the factors involved with successful sports participation for every child, like the importance of the development of motor competence and an early focus on diversification rather than specialisation in youth athletic development. Apart from adding to the general literature on the subjects of motor competence (measurement) and the early diversification versus early specialisation debate, this thesis also has some practical implications. First of all, it shows that general motor competence assessment using the KTK could play an important role in the identification of children at risk of developing low levels of motor competence, as they are also at risk of developing low levels of physical fitness and are less involved in sports in general. Measuring and understanding changes in motor competence over time may lead to effective interventions aimed at improving/maintaining motor competence in all children. Furthermore, the KTK is a tool for motor competence assessment that can easily be used in the field by sports practitioners, coaches and other sports officials as its practicality and usefulness in a broad population seems to be unrivalled. Hence, a motor competence assessment screening at regular time intervals in all children up to 12 years old is a great way to successfully map the changes in motor competence in these children over time. By making the motor competence assessment mandatory for all children under 12 years (just like mandatory nation-wide reading and math tests), a nation-wide screening could be organised in order to successfully map changes in motor competence in all Flemish children over time. Using the KTK, a teacher could measure a group of 25 students in about two hours (e.g. a physical education session).

Also, frequent measurement of motor competence will allow for children with a relatively high or low motor competence compared to their peers to be identified at an early age. This way, these children can receive a proper management of their shortcomings or talents. Faigenbaum and colleagues (2011) showed that an eight-week program of two 12-minute sessions of fundamental motor skill training per week significantly improved push-up, 1/2 mile run, single leg hop and long jump performance in 7.5 year old children. Also, Bardid and colleagues (*2013*) showed that a 10-week fundamental skill program had a positive effect on motor competence. Therefore, when children are identified as having a relatively low motor competence, they should be able to enter in school-based physical education programs with a particular focus on improving the motor competence in these children. To structure these programs, remedial classes could be created in the same way remedial classes are created for children that have difficulties with other subjects in school like language, math, sciences, etc. These classes would involve any child diagnosed with a low motor competence for as long as necessary (until the following measurement shows an ample improvement in motor competence).

Based on previous literature and the findings in this thesis, the diversification pathway proposed by Côté and colleagues in the DMSP (1999), seems to be a valuable alternative for early specialisation as a pathway to expertise. However, the major reason why the DMSP should be the preferred developmental pathway used by anyone involved in youth sports is that the DMSP model also shows an outcome for less talented individuals. While the early specialisation pathway can be considered exclusive (only talented athletes reach expertise in their domain), the diversification serves a broader setting such as recreational sports participation and even physical education while still upholding a pathway to expertise for those children with exceptional abilities. Therefore, the early diversification model should be the 'golden standard' used in the development of youth sports involvement. There is a strong connection between the first section of this thesis on motor competence and the second section on the specialisation versus diversification pathways. From the research in this dissertation, it was apparent that 10-12 year old children who participate in more than one sport have higher scores on the KTK than those who specialise in one sport, although no causal relationship was revealed. Children who participate in more than one sport need to be motor competent since they need to be able to use and quickly master a large variety of motor skills. Whether these children participate in different sports because they are competent or whether the participation in more than one sport has made them more competent is still unclear. However, it can be concluded that in the developmental stage between 6-12 years, the emphasis should be on increasing motor competence in all children.

The 'grey area' in athlete development between 12 and 18 years is often overlooked in scientific research. In the DMSP (Côté et al., 1999), players move from the sampling to the specialising stage or from the specialising to the investment stage with time. While sampling and the involvement in deliberate play are the main goals of the sampling stage, the specialising and investment stages involve gradually increasing amounts of highly specific training. However, some coaches seem to be driven by outcome rather than process of progress and are willing to sacrifice development over performance. Therefore, they seem to advocate complete instead of gradual specialisation at a relatively young age (between 12-16 years). We believe that advising coaches on the possible detrimental effects of complete specialisation at this stage of development is beneficial to their understanding of the pathways that lead to successful sports involvement. Hence, it is of importance to emphasize process over performance.

This dissertation advocates a strong focus on sampling and motor competence development in young children. However, for sports clubs, physical education programs and other sports initiatives, adhering to this guideline is not straightforward. Therefore, an 'umbrella organisation' that is responsible for organising testing sessions aimed at identifying talented children and those at risk of developing low motor competence, for structuring and organising training sessions with the aim of improving motor competence in children and for raising awareness about the pathways to successful sports involvement through conferences, club visits, coach education courses etc. might help these clubs, schools and other sports organisations better structure their long-term plans for the development of successful sports involvement in all children.

C. Directions for future research

Based on the framework presented in this dissertation, it is important for studies on motor competence and its effect on physical fitness and sports participation to follow children from three years well into adulthood. However, longitudinal research covering large periods of time is difficult. Hence, shorter-term follow up studies using age cohorts that represent different stages in motor development (3-6, 6-9, 9-12, 12-15, 15-18 and 18+ years) are decent replacements for longitudinal research. Special attention in future research should be paid to the presumed 'sensitive window' of motor competence development (before 12 years). To do so, it is important for researchers to establish validity and reliability for the motor competence assessment instruments used. Studies on the development of motor competence should also include measures of physical fitness, a measure for perceived motor competence and an objective measurement of physical activity, as the interaction between fitness, physical activity and (perceived) motor competence has clearly been implied, but not rigidly established through longitudinal research.

Further research concerning the pathways towards sports involvement should adopt a longitudinal methodology (age 6-18 years) to assess possible differences in the development of physical fitness and motor competence between boys and girls adhering to a sampling or specialisation pathway. There has been no longitudinal research that uses a follow-up of children to investigate the possible beneficial effect of sampling on measures of physical fitness or motor competence. The inclusion of children up to 18 years in a longitudinal study will allow researchers to take a closer look at the stages of development following the sampling stage (specialisation and investment stage), as no research specifically on these stages of development exists. Future research on the diversification versus specialisation pathways should also include a measurement of sports participation history, as looking well into the sports history of individuals from different sports may reveal details on whether and when a diversification or specialisation pathway is/was implemented.

D. References

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