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Contribution of Anthropometry, Physical Performance and Coordination Attributes to Talent Identification in Combat Sports

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PART 1: INTRODUCTION

1. An introduction to sports talent in an international context

The identification of talent is a common characteristic of all domains of human development, spanning areas like sports, academic education, arts, and many others. Researchers in these areas have made attempts to find the best way to identify talent in their specific fields. With respect to a clear definition of talent, it appears that it can mean whatever a business leader, sports coach, or writer wants it to mean, since everyone has his or her own idea of what the construct does and does not encompass (Ulrich, 2011). In spite of the lack of a clear definition of talent spanning all areas of human development, talent can be characterised as "a special ability that allows someone to reach excellence in some activity in a given domain" (Issurin, 2017).

One of the popular models related to talent in sports was developed by Williams and Reilly (2000), who called it 'the pursuit of excellence'. The model suggests four successive stages with relevant targets and content. The first stage is *talent detection* which can be defined as a process of discovering the potential in young performers not engaged in a specific sport yet. The second stage is called *talent identification* and is directed to identifying individuals that can potentially develop into elite athlete in the future in a specific sport. Once a talented individual has been identified, he or she enters the third stage of *talent development*. During this phase, the athlete is provided with a suitable learning environment and resources that should facilitate the transformation into an elite performer. Elite athletes then enter the fourth stage of *talent selection*, encompassing the selection of an individual / team for a specific occasion, for example the Olympic Games. These athletes compete at the highest possible level in sports. In this study, we will concentrate on the second stage (*talent identification*) of this model to define the potential young athletes in combat sports.

In the previous set of definitions, talent is already used in the very early stage of the sports career of an individual. However, Gagné proposed a more differentiated model in which he separated ‘giftedeness’ from ‘talent’ in young athletes. In his *Differentiated Model of Giftedness and Talent (DMGT*; Gagné, 2004) he defined giftedness as the possession and use of untrained and spontaneously expressed natural abilities (gifts) in at least one ability domain to a degree that places an individual at least among the top 10% of age peers. Meanwhile, talent designates the superior mastery of systematically developed abilities and knowledge in at least one field of human activity to a degree that places an individual at least among the top 10% of age peers who are or have been active in that field or fields. (Gagné, 2004). In addition to the valuable addition to the discussion on the true meaning of talent, the DGMT model will be explained in detail further in this introductory chapter because it also taps into the potential mechanisms that might promote or hinder the development from gifts into talent.

The domain of sport is omnipresent both on a national and worldwide level. What factors will contribute to the success of athletes, has been the subject of debate throughout the years. De Bosscher (2008) compared and discussed data collected from six sample nations to evaluate and compare the success of different nations on the international sports scene. She identified nine pillars needed in order to develop a good talent system and produce a world-class athlete capable of winning medals in Olympic games; 1) financial support; 2) integrated approach to policy development; 3) participation in sport; 4) *talent identification*; 5) athletic and post career support; 6) training facilities; 7) coaching provision and coach development; 8) international competition; and 9) scientific research. Overall, most of the nations provide some level of funding for scientific research in elite sport but none of the nations has a nationally coordinated program of co-operation with universities and higher education establishments for the purpose of scientific research. De Bosscher (2008) suggested four pillars as key success drivers (financial resources, athletic career support, training facilities, coach development) and three under developed areas where nations may gain a competitive advantage. Scientific research, coaches' provisions, and talent identification and development systems were the three areas with large growth potential.

The talent identification system of the former German Democratic Republic (GDR) was the pioneer of various successful talent systems. Some of the key ideas in this system were later adopted by the Australian Institute of Sport (AIS), the Talent Identification Unit at Japan Sport Council, and UK Sport Performance Pathway Team (Pion, 2015). All young children were systematically included in this program, which contrasted with the western policy that was more inclined to support talented athletes after they became successful. Generally, GDR athletes specialized earlier in one sport and participated less in other sports. They spent more time on specialized training during youth and adulthood and had more access to systematic athlete services delivered by scientists, medical specialists or career counselors. Many of these athletes achieved greater success during their youth but were often unable to continue this success at senior level. As a result, in spite of a huge number of medals obtained at international competitions in the 80's, the economic inefficiency at the collective level of many sport organizations is apparently mirrored in lower efficiency of investment at the individual level of Eastern athletic careers (Güllich & Emrich 2013).

The search for talented athletes became however an important matter for a lot of countries and added to their struggle to gain Olympic medals. The Australian Sports Commission in 1989 chose to focus on target sports in which Australia could do well internationally, and seven sports were chosen. A total of $10 million was allocated for the program and was divided between cycling, hockey, basketball, rowing, canoeing, swimming and track and field. The Australian

Institute (AIS) developed the first successful talent detection programme in the western world called the 'Talent Search'. This program was inspired by Dr. Hahn's successful detection of talent in rowing and led to the Australian rowers being fast tracked to the 1992 and 1996 Olympics (Tranckle, 2005). The medal tally (overall) increased from 14 in Seoul 1988 to 27 in Barcelona 1992 to 41 in Atlanta 1996, reaching a total of 58 in Sydney in 2000 (Bloomfield, 2003).

Talent programs with a large sum of funding were launched in the new millennium with China and Great Britain having set specific targets to increase their medal count at the Olympics. China’s ‘Project 119’ was launched in 2002. The name of the program alluded to the number of medals that China wanted to achieve during the Olympic Games in their own country in 2008 (Jones, 2008). The government supported athletes in sports that traditionally yielded less medals in previous Olympics, with unlimited funds to achieve success in athletics, canoeing, rowing, sailing and swimming.

In Britain, the UK Sport programs were launched in 2002 as a preparation for the 2012 London Olympics. UK Sport generates most of the funds and is considered a bank that stands between the government and the sports federations. The main mission is to enhance the climate of the sport performance monitoring and evaluation of sport systems and structures. Within the program five stages, namely talent identification, talent selection, talent transfer, talent confirmation and World-class development succeed each other. The success of this well organized system was shown in the medal standings at the London Olympics in 2012.

China’s and Great Britain’s programs might be a good example but cannot be copied in a straightforward way to smaller countries with a lower population and fewer financial resources. Other countries have applied alternative talent programs that suit their environment and needs.

The Netherlands and Canada implemented the Long Term Athlete Development (LTAD) model (Balyi, 2001 and 2007), focusing on the general development of the athlete.

The Japanese model (Kinugasa, 2014) offers new dimensions to existing systems and their target is Tokyo 2020. The model is a combination of short-term actions and long-term projects, which includes talent detection; talent identification and talent transfer resulting in 700 selected athletes for 12 regional centers. There are three different types of talent academies in this model. Firstly, is the classic talent academy with preliminary screenings and selections in a particular sport, followed by specific Talent Transfer Centres that try to transform outstanding athletes towards high performances in new sports that suit their abilities better. Lastly, the new Multi-Sport Centres develops high potentials (12-14y) by means of sports clusters. This high level generic development based on clustered talent characteristics leads towards a future sports specialization.

In Flanders (Belgium), the Flemish Sport Compass (FSC) was developed, based upon the observation that elite adolescent athletes showed differences in generic (i.e. non-sport specific) talent characteristics that allow to discriminate them from participants in other sports (Pion, 2015). The participants for that study had been selected by their sport federations for the Flemish top sport schools (TSS). The TSS were initiated 20 years ago and the talent identification program was implemented with the aim of identifying the best athletes at an early age. Every year there is a selection process to enter the TSS and those who meet the criteria will be offered to participate in the TSS program. Even though a large number of athletes develop within the TSS system, a substantial number of young elite athletes still develop outside of this program. The limited number of sports that are included in the TSS program is one of the reasons why some of the young athletes are not in the TSS program and therefore they have no other option but to continue their training in the club or federation to become an elite athlete. The methodology used in the FSC is discussed further in this chapter.

Previous studies have tried to identify the indicators that predict success at the elite level and this area of research has attracted a great deal of attention (e.g., Abbott & Collins, 2004; Hoare & Warr, 2000; Reilly, Williams, Nevill, & Franks, 2000; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). Although one would expect systematic differences in athlete profiles according to performance level, such differences appear to be sport-specific to a certain level. For example, several studies reported no significant differences in the anthropometric characteristics between athletes of different levels in female water polo (Martinez et al., 2015), powerlifters (Keogh,Hume,Pearson & Mellow, 2007) and ice hockey (Agre et al., 2012).

Studies have focused on the development, identification and selection of athletes based on physiological, biomechanical, psychological and sociological characteristics (e.g., Abbott & Collins, 2004; Mohamed et al., 2009). Some studies have examined the technical and scientific aspects of talent identification and the development process such as coaching techniques, sports sciences and technological advancements (e.g., Balyi & Hamilton, 2004; Bloom, 1985; Baker, Cote´, & Abernethy, 2003; Cote´ & Fraser-Thomas, 2007). Others put more emphasis on the socio- cultural dimensions of athlete development such as unequal economic opportunities (e.g., Maguire & Pearton, 2000), or the birthplace of athletes (e.g., Cote´, Macdonald, Baker, & Abernethy, 2006). Those studies underline the complexity of talent identification and the difficulty of measuring talent and recognizing talented athletes. The following paragraphs will focus on the theoretical model of Gagné (2004) that aims at the integration and understanding of this wide variety of factors.

2. The Differentiated Model of Giftedness and Talent

2.1. General introduction to DMGT

A talent model that is widely accepted among scholars is The Differentiated Model of Giftedness and Talent (DMGT) by Gagné (2004) that combines factors such as natural abilities, intrapersonal attributes, chance, and environmental influences as key factors in talent programs. Gagné (Figure 1) suggested a clear distinction between constituent elements (giftedness) and an end product of development (talent) via the Differentiated Model of Giftedness and Talent.

The DMGT model starts from natural abilities or giftedness that can flourish when the right developmental processes and circumstances can be applied. Along this process, intrapersonal as well as environmental catalysts that can help to reach the absolute top level of skill. According to Gagné, about 10% of the individuals identified as belonging to the top 10% for a specific gift will be able to effectively transform into sports talents. Each of the components suggests broad domains and they have a direct or indirect relationship with each other.

From this model, it is clear that the development from giftedness into talent in sport cannot be explained from a unidimensional perspective. Multiple intrinsic and extrinsic factors will affect the career of a child that is interested in a career in sport. Extrinsic factors are multiple in this respect. Among these environmental catalysts were parental and peer support, socio-economic factors, or the quality of coaches and developmental programs. For example, a supportive parent and living in a favourable socio-economic situation will increase the chance that children get into contact with sport and that the support for development of its capacities is guaranteed. Family environment, including provision of equipment, financial, logistic and emotional support and parental modelling are positively associated with sport participation (Timperio et al, 2013).

In the model of Gagné, the sensorimotor factors (highlighted) under Natural Abilities refer to motor abilities or physical performance capacities that could be observed through motor and physical fitness tests. The measurement of physical and motor abilities is generally the cornerstone in talent systems to define the best performer or better mover. Physical abilities measured using several tests that represent the physical characteristics such as strength, endurance, speed, and endurance are often called the main components of physical fitness (Caspersen et al, 1985).

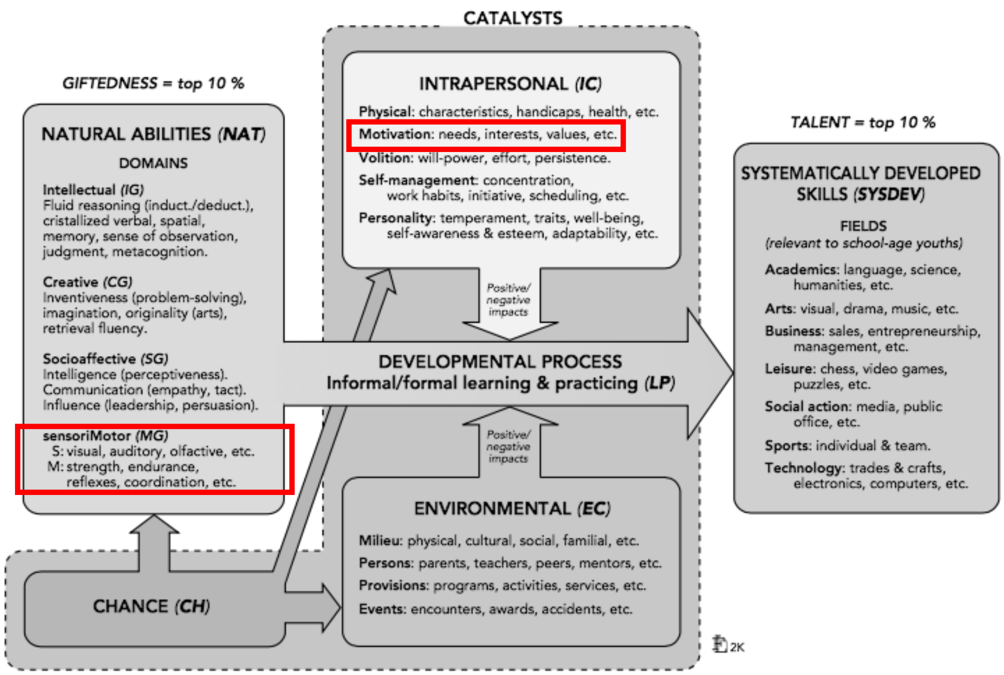

Figure 1 : Gagné’s Differentiated Model of Giftedness and Talent (DMGT)

2.2. Highlight: intrapersonal characteristics of the DMGT model

Among the intrapersonal catalysts, motivation has been mentioned as one of the important characteristics that can help to develop skills or talent in young athletes. Only highly motivated individuals will be able to persevere in the high training loads necessary to reach the top and to stay there as long as possible. Part of the motivation lies in the enjoyment that children, adolescents, and senior athletes experience while practising their sport. This feeling can help them to overcome difficult periods throughout the career. For example, Schmidt and Stein (1991) mentioned the importance of enjoyment in reducing the incidence of dropout and burnout in sport. Moreover, the fun/enjoyment aspect was the most commonly reported as an intrinsic motivator for sport participation among children and youth (Sirard et al., 2006; Whitehead & Biddle, 2008).

Children that experience joy during movement activities or sport participation are more likely to continue to be involved. From this, enjoyment can be considered as a factor that positively affects a child’s motivation to be active in sports. This issue has been discussed for the past decades by researchers, not only for talent development or dropout in sport but also to enhance the involvement in sport as a recreational activity as a health purpose. The achievement goal theory (Nicholls, 1989) and the self-determination theory (SDT) (Deci & Ryan, 2000) are the two general theories that have been used to explain childrens’ reasons for participating in sport. Achievement goal theory refers to the principle that children’s motivations are situated along a task or ego-orientated continuum. Children who are more ego-orientated are more motivated because they aim for superiority in terms of winning competitions and gaining recognition, whereas those who are task-orientated are concerned with personal improvement though the learning of new skills (Quested & Duda, 2011). According to SDT (Deci & Ryan, 2000), when individuals engage in physical activity because they experience enjoyment and satisfaction directly from participation, they are intrinsically motivated, with the latter reflecting the most self-determined regulation of behavior.

One of the main purposes for children taking part in sports is to have fun and participate in enjoyable experiences. Enjoyment is a multidimensional construct related to affect, excitement, perceptions of competence, attitude, and cognition (Hashim et al., 2008; Wankel, 1997). Meanwhile, youth in several cultures indicate fun (enjoyment) as a primary motivation for participation in sport (Coelho e Silva & Malina 2009; Siegel et al. 2009). It can be just simply running around with friends or competing with peers and winning. The level of enjoyment almost always appears as one of the primary reasons for participating or dropping out from sport (Weiss & Amorose, 2008; Green, 2005; Siegel et al. 2009; Cote, Baker & Abernethy, 2007). Therefore, children's experiences in sport or physical activity will determine whether they will be active or otherwise.

Intrinsic motivation has been shown to be positively associated with physical activity (De Meester et al., 2016). Motivational aspects such as enjoyment seem to be an important attribute that affect the involvement in an active life style. Researchers have demonstrated the significance of enjoyment as a key factor underlying the motivation for children and youth to maintain positive engagement in physical activity (e.g. Prochaska et al., 2003; Wallhead and Buckworth, 2004). Children with good motivation are more likely to remain active and participate more in physical activity, which will allow them to discover their potential or talent. In the recreational years, children participate regularly in sports without aspiring to reach an elite level of performance during which the key characteristics are health and enjoyment (Côté and Hay 2002).

The model by Stodden et al. (2008) mentioned that during early childhood, changes in motor competence are mainly driven by the engagement in physical activity. The authors also hypothesize that the relationship between motor competence, physical fitness and physical activity strengthens over time. Generally, physical activity levels will influence the development of children’s motor competence. Previous studies reported that low-skilled children will become less motivated to continue to participate in physical activity, games or sports (Stodden et al., 2008; Deci & Ryan, 2000). Based on the health aspect, it is important to be active in physical activity to stay healthy and it should be practiced in the younger ages. Meanwhile, increasing numbers of children who participate in physical activity or stay active in sport could also help to increase the numbers of talented group/children.

It is reasonable to assume that highly motivated children will stay active and with the right guidance they can maximize their talent. This process will in turn make the pool of talented young athletes larger. From this point of view, many models in the literature have discussed the level of sport participation as the basis for the creation of a talent pool (Fransen, 2014). In the pyramid of development of specific sports competencies, the first level is that of sport participation. This is where the processes of talent detection usually occur for the first time, at least in part of the children. The step towards sports participation is affected by many factors such as finances (Holt, Kingsley, Tink & Scherer, 2011), friends (Weiss, Smith & Theeboom, 1996) and parental influence (Brustad, 1993), while the level of enjoyment by the child itself is often overlooked. Enjoyment in being active and participating in sport is assumed to be an important prerequisite for remaining motivated to do so. From this perspective, it makes sense to get more insight in this aspect, which is the main aim of the final experimental chapter of this dissertation (see next paragraphs).

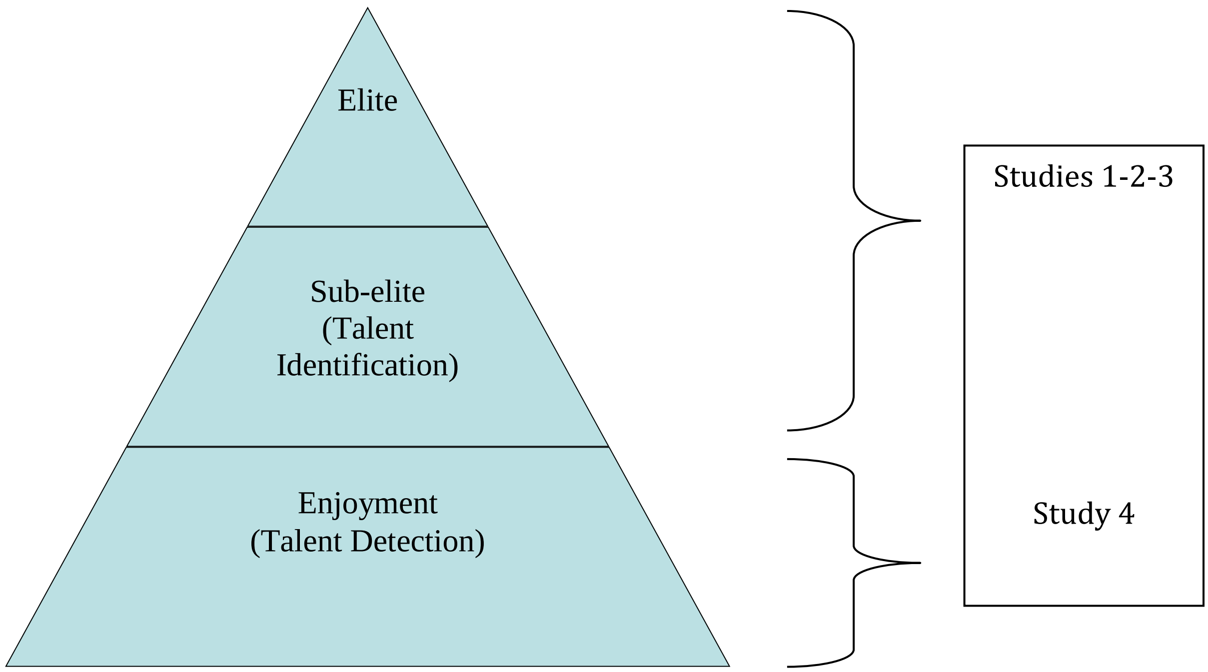

Figure 2: Studies in this dissertation in relation to the elite sports pyramid.

3. A model for the study of TID in combat sports

3.1. The Expert Performance Approach

The Expert Performance Approach (EPA) originally introduced by Groot in 1965 and elaborated by Ericsson and Smith (1991), promoting three ecological steps that are commonly used by researchers in sport, is used as the general framework for the study of TID in combat sports in this dissertation. Williams and Ericsson (2005) described the three steps (Figure 3) as i) capture expert performance, ii) identify underlying mechanisms and iii) examine how expertise is developed. Those three steps are a combination of several factors such as laboratory-testing, field-testing, process-tracing measures, practice history profiling and learning studies.

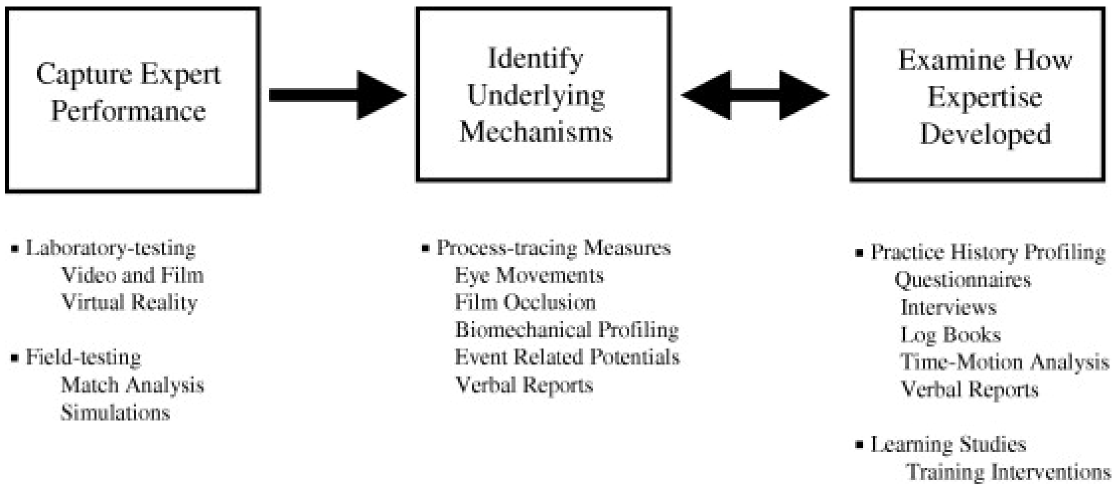

Figure 3: The expert performance approach and some of the methods and measures that may be used at each stage (William & Ericson, 2005)

The first stage of the Expert Performance Approach is capturing expert performance that involves laboratory or field based analysis/testing, which should provide a consistent measurement of performance (Ericsson & Smith, 1991). The main goal of this stage is to capture the expert within their domain, therefore, if a laboratory setting is used, it needs to strictly replicate the same processes experts use in their discipline (Williams & Ericsson, 2005). In studies 1 to 3, we will capture expert performance for combat athletes based on the literature available. Previous studies have mentioned the background of the combat sports such as the time course of a competition, the rules and regulations, the type of efforts that are common during the combat, and the processes that lead to a decision on who wins the competition. That information will give us ideas on the nature and the amount of an expert's activity, especially in the tournament situation.

The second stage of the Expert Performance Approach identifies mechanisms underlying expert performance (Ericsson & Smith, 1991). In other words, this phase focuses on the individual or team characteristics an athlete must possess in order to meet the demands of the competition as described in the first stage. In this dissertation, the second stage of the Expert Performance Approach will consist of data collection and testing selected groups of combat sport athletes of different levels and disciplines. Anthropometric characteristics, physical performances profiles, an evaluation of the level of general motor coordination, and additional data like training history will be collected. Based on the data, we will define which components are different or significantly related to their performance. The third stage which aims to improve understanding of how adaptations occur during acquisition of expertise and to use the knowledge acquired to develop training interventions that helps facilitate the more rapid acquisition of expertise.

3.2. The Flemish Sports Compass

Preceding studies on The Flemish Sports Compass (FSC; Pion, 2015) aimed at, among other purposes, directing children into specific sports using generic test batteries. The FSC test batteries consists of anthropometric, physical performance and motor performance measurements which help in the process of talent identification, talent orientation and talent detection. The FSC started in 2007 and has generated profiles of thousands of children and adolescents, participating in different sports and performing at a wide variety of levels. In spite of the funding of this project ending in 2013, data collection by means of the same standardised test battery has been continued since then. The huge amount of data collected is now a reference data base in which longitudinal follow-ups are being conducted now. This is a source for valuable information with the potential to optimise a performance talent identification program for Flanders. The FSC tests are also applicable in both elementary school children and in Flemish top sport school children. By means of the FSC, it is possible to discriminate between different performance levels and detect sport specific characteristics of an individual. In this study, we will apply the method from the FSC to distinguish combat sport athletes in various levels of achievement or participation. This study will also use some of the data that have been collected for the study of the FSC and it will be continued from the FSC research but focused on combat sport athletes.

Anthropometric, physical performance, and motor coordination profiles have been collected in boys and girls from wide range of sports, calendar ages, biological ages, and performance levels. Specifically related to elite performance, the number of athletes in a study is typically low, which hinders the application of standard statistical techniques. When interpreting test results, raw scores do not mean much unless they can be compared to other scores (Pion, 2015). Previous studies (Matsudo, 1987; Matsudo, 1996; Pion, 2015) have implemented the z-score method to make a clear distinction between the samples in their studies. Later, the z-score method has been adapted and recalculated into the motor quotient score by Kiphard and Schilling (2007) and Ahnert, Schneider, and Bös (2009) aimed at positioning children in relation to their peers with respect to motor coordination. The z-score method will give a new score that can be used as a baseline and is an applicable method especially when dealing with small sample sizes.

There is still a lack of studies that discuss the differences between combat sport athletes and the different levels of achievement. This study will focus on differences between Judo athletes, Taekwondo athletes and Fencing athletes in different levels of achievement or participation. Using the FSC methods, we will gather the information regarding their anthropometric measurements, physical performance tests and motor coordination tests. In the next phase, we will define the characteristics of combat sports and the athletes active in it to investigate to what extent the three groups of tests in the FSC can distinguish between the elite and the non-elite groups.

4. Performance profiles and athletes' characteristics in combat sports

4.1 Combat Sports

Around 25% of all Olympic medals disputed come from combat sports (Franchini, Brito & Artioli, 2012). Male and female athletes in judo, taekwondo, fencing, boxing karate and free style wrestling will compete at the Tokyo 2020 Olympics and there will be medals for team events in fencing and judo (Franchini, Cormack & Takito, 2019). Recognition of combat sports in the Olympics underline the significance of these sports, and at the same time stimulate researchers to conduct studies that might subserve talent systems in combat sports.

Previous studies used the terms of MACS (Martial Arts and Combat Sports; Channon & Jennings, 2014; Del Vecchio et al., 2018; Jennings, 2013) to discuss their findings referring to martial arts or combat sports. Moreover, martial arts (e.g., karate, judo, kickboxing, taekwondo) participation has universal appeal (Vertonghen & Theeboom, 2010). Martial arts are divided according to technical characteristics such as "hard" versus "soft", or "striking" versus "grappling" styles (Donohue & Taylor, 1994). A combat sport is an involvement of two individual combatants fighting each other using specific techniques (kicking, striking and weapons) and respecting prearranged rules (Noh et al., 2015). Different cultures and different historical moments are linked to different names (Figueiredo, 2009, Vertonghen, 2011). From literature it appears that the terms of martial art or combat sport are used interchangeably, but within the framework of this dissertation the phrasing 'combat sport' will be used.

Combat sports such as Wushu, Wrestling, Taekwondo, Sumo, Karate, Judo, Fencing and many more are sports integrated in GAISF (General Assembly of International Sports Federation). At the end of 19 century and the early decades of the 20th century, most of them became institutionalized in Asian countries led by Japan with, among others, Judo and Sumo (Figueiredo, 2009). Some of the sports originated and/or developed in Europe and became part of the program of the Olympic Games, like fencing and boxing. Many of them still build upon fighting techniques that were originally used in war or real fight. Most of combat sports have very strict rules or regulations to ensure the safety of athletes during the competition.

Combat sports are competitive contact sports that normally involve one-on-one combat and the winner is usually declared based upon scoring more points than the opponent or by preventing the opponent from continuing the fight. Different combat sports involve different moves and skill sets. For example, judo athletes use their hand to grip the opponent (Sato, 2013) while taekwondo mostly involves kicks or punches (Bridge, Jones, & Drust, 2009). There are also some combat sports that involve the use of weapons, such as fencing with three weapon categories (foil, saber and epee; Gaugler, 2004).

Nowadays, combat sports have a significant place in the realm of sport and they are also included in many international multi-sport events (Olympic Games), as well having their exclusive event in the World Combat Games and each sports world championship (Tabben et al., 2014). Besides that, the popularity of these sports is flourishing (van Bottenburg, Rijnen, & van Sterkenburg, 2005; Ifedi, 2008) among different ages, for a variety of reasons such as maintaining physical fitness, improving characteristics like balance, flexibility and strength, and/or gaining health benefits (Woodward, 2009; Zetaruk, Violan, Zurakowski & Micheli, 2000). Despite their popularity and the determination of physical and physiological profiles of taekwondo (Bridge et al., 2014; Marković et al, 2005; Kazemi et al, 2010), judo (Tabben et al, 2014; Yamamoto, 2006) and fencing (Borysiuk, & Cynarski, 2010; Turner et al., 2014) in adult athletes, to our knowledge, only few studies have focused on young combative athletes, with respect to their anthropometric, physical performance and motor coordination characteristics

(Pion et al, 2014; Norjali et al., 2017). The information of those characteristics could be useful for talent detection, identification, development and selection programs.

4.2 Sport Characteristics

Every sport has its own characteristics including specific rules and regulations. It is important to understand the characteristics of the sport to get general information of the constraints of the competition in combat sports (e.g. scoring system, materials, etc..). These characteristics obtained during the first phase of the Expert Performance Approach of Ericsson & Smith (1991) will determine the ideal profile of a given athlete with the ambition to excel in a particular sport.

The time-motion studies reported that striking combat sports such as taekwondo (Santos, Franchini & Lima-Silva, 2011), as well as weapon-based combat sport like fencing (Wylde, Tan & O'Donoghue, 2013), are featured by shorter high-intensity efforts interspersed by longer pause periods compared with grappling combat sports such as judo (Miarka at al., 2012).

Franchini, Artioli & Brito (2013) mentioned that the effort-pause ratio during judo combats is between 2:1 and 3:1, with 20s and 30s effort periods and 10s of pauses. The study also shows that judo athletes rely on all three metabolisms, with the anaerobic alactic system being responsible for the short duration powerful actions during technique applications, the anaerobic lactic system being responsible for the maintenance of high-intensity actions during longer periods (e.g., grip dispute), while the aerobic system is responsible for the recovery processes between high-intensity actions and matches.

General characteristics on Taekwondo are described in previous work (Tornello et al.,2013) that mentioned several points such as (a) the intermittent nature of combats characterized by a 1:2 ratio of fighting and nonfighting phases, (b) a high sparring intensity determined by a high occurrence of tactical movements and technical exchanges during fighting, and (c) duration of activities and intensity of combats similar for gender and weight division of athletes, independent from round and tournament stage.

In the fencing competition, a foil fencer will work for 5 seconds, whereas an epee fencer will work for 15 seconds (much of which is submaximal) before each rest period or interruption. Furthermore, during each bout in fencing, a fencer may cover between 250 and 1,000 m, attack 140 times, and change direction nearly 170 times in men's epee and foil (Turner et al., 2014) and around 133 times in women's sword fencers (Roi & Pittaluga, 1997).

The examples above illustrate that combat sports have much in common when it comes to the temporal structure of the competitions and the global dependence of different systems for energy supply. In the next sections we will go into more detail for the three combat sports in this dissertation.

4.2.1 Judo

In 1882, a young Japanese University graduate founded judo and several of his followers and pupils opened a school at Eiosho-ji temple (Sato, 2013). Judo is a combination of various traditions of Japanese martial arts sometimes called bujutsu (martial technique) or bugei (literally, 'martial art'). These martial arts were practiced by the samurai lords as methods of physical training, particularly when Japan was ruled by the shogun of Tokugawa family. In the beginning of the 20th century, Judo went beyond Japan's borders with the opening of Kodokan branches in America, Germany, France and Britain. Judo became more popular and spread around the world during the World War II and the early post-war years.

The International Judo Federation (IJF) was founded in 1951 and judo was included in 1964 Summer Olympic Games programme, the men events has been introduced. The womens' event was introduced as a demonstration event at the 1988 Seoul Olympic games and became an official event in the 1992 Barcelona Olympic games. There are 7 weight categories, which are different for males and females. In competition, two contestants, normally one wearing a blue outfit and the other wearing white, fight each other in 4 minutes of time, where the aim is to either throw or takedown an opponent to the ground. A contestant can win the match by throwing their opponent, holding the opponent on his or her back for a certain amount of time, applying a submission hold on the elbow joint, or choking the opponent; a contestant can also win if the opponent commits certain rule violations (Sato, 2013). In general, the real competition situation in Judo can be found in the study conducted by Chalis (2015). Chalis demonstrated that based on an average score, hajime to matte (work blocks) occurred 11 times, matte to hajime (rest blocks) occurred 9.9 times, kumi-kata sequences (gripping sequences) 12.5 times and ne-waza sequences (ground work) occurred 3.6 times per contest on average. Nage waza remain the most important techniques in judo match and the most used techniques in ground position are hold down techniques (Segedi, Sertic, Franjic, Kustro & Rozac, 2014).

Based on the study by Franchini, Artioli & Brito (2013), it is possible to observe that periods of activity in Judo competition are vary from 10s to 63s and pause periods vary from 1s to 22s, while the activity-pause ratio is normally 2:1 or 3:1. This seems to be similar between mens's and womens' competitions (Hernández-García and Torres-Luque, 2007; Wicks, 2006). Furthermore, judo athletes seem to engage in shorter effort periods and longer intervals in the last minute compared to the previous ones (Monteiro, 1995), which can be interpreted as an effect of fatigue on technical-tactical actions.

Previous studies have found higher lactate values than those found after match simulations, suggesting that competitive matches are more reliant on glycolytic metabolism than match simulations. Blood lactate values after match simulations reach ~10 $mmol.l^{-1}$ and real competition shows that high glycolytic solicitation results in blood pH decreases to 7.090±0.092 mmol.l-1 (Mickiewitz et al., 1991) and seems to be consistent across different age groups (Majean and Gaillat, 1986). Although Franchini et al. (2011) reported that the highest-level athletes presented lower blood lactate compared to lower level but no differences in blood lactate concentration were found between winners and defeated athletes in regional level competition (Nunes, 1998). This result suggests that more technical athletes rely less on the glycolitic system.

4.2.2 Taekwondo

Taekwondo is a Korean martial art that consists of various techniques and skills such as spinning and jumping kick, head-height kick, and fast kicking techniques. Korean martial artists with a broad experience in martial art have developed Taekwondo during 1940s and 1950s. The international federation governing the sport called World Taekwondo Federation until June 2017, and now they renamed it as World Taekwondo and are a member of Association of Summer Olympic International Federations (ASOIF). In Korean, “tae” means, “foot”; “kwon” means “fist”; and “do” means “way”; so “taekwondo” is loosely translated as “the way of the foot and fist” but can be best translated as, “the art of kicking and punching” (Park, 2009).

Taekwondo officially became an Olympic sport in the 2000 Sydney Olympics after being demonstrated in the 1988 Seoul Olympics and the 1992 Barcelona Olympics (Kazemi, Waalen, Morgan, & White, 2006). “Kyeorugi”, or sparring, is an official Olympic sporting event and there are 4 weight categories, which are different for males and females. The sport element of

Taekwondo consists of weight-governed, full-contact combat between two opponents and winner is decided via knockout of the opponent or a greater number of points using kicking and punching techniques to legitimate targets (Bridge, Jones, & Drust, 2009). While punching to the head is not permitted, kicks to the head and face are allowed. The duration of the contest shall be three rounds of two minutes each, with a one-minute rest period between rounds. In case of a tie score after the completion of the 3rd round, a 4th round of one minute will be conducted as the Golden round, after a one-minute rest period following the 3rd round.

Regardless of gender and grouped weight division, Tornello et al. (2013) reported that combat phases in taekwondo consists, on average, of 42.2% fighting, 44.5% not fighting and 13.1% stoppage time. The mean duration of such a typical combat phase is 2.8s fighting, 6.5s not fighting and 13.7s stoppage time. The study did not result in differences for frequency of occurrence and mean duration of tactical movements and technical exchanges.

Matsushigue, Hartmann & Franchini, (2009) mentioned that post-match blood lactate concentration was 7.5 mmol.L^{-1} and high-intensity movement was 31 seconds. The mean effort time (8 seconds) did not differ from mean interval time (8 seconds). Winners used a smaller total number of techniques, but post-match blood lactate concentration did not differ from that of non-winners. The study (Matsushigue, Hartmann & Franchini, 2009) conclude that glycolytic metabolism was not the predominant energy source and the physiological responses did not differ between winners and non-winners.

Male taekwondo athletes, who compete in international level recorded that heart rate (round 1: 175 to round 3: 187 beats·min−1), percentage of heart rate maximum (round 1: 89 to round 3: 96%) and rating of perceived exertion (round 1: 11 ± 2 to round 3: 14 ± 2; $P < .05$; mean ± SD) increased across rounds (Bridge, Jones & Drust, 2009). International taekwondo athletes use near-maximal cardiovascular responses in competition. Therefore, training should also include exercise bouts that sufficiently stimulate both aerobic and anaerobic metabolism. Moreover, the contribution of the aerobic, anaerobic alactic and anaerobic lactic energy system were estimated as 120kJ (66%), 54kJ (30%) and 8.5kJ (4%) (Campos et al., 2012).

4.2.3 Fencing

Fencing history begins in ancient Egypt roughly circa 1200 BC. Over 3000 years ago, paintings depicted fencing bouts where sticks were used instead of swords in combat. However, the fencing that we see today more likely originated in Spain in the fifteenth century, which involved more thrusting than the fencing done by the ancient Egyptians (Amberger, 1999). The International Fencing Federation commonly known as FIE has been established since 1913, where fencing was first introduced as part of the first modern Olympics which were held in Athens, Greece 1896. Women competed for the first time at the Olympic games in Paris in 1924.

Generally, the apparatus needs to touch certain spots or parts on the body to generate points and the fencer with the highest score will be the winner. There are three types of weapons or events in fencing which are the foil, the sabre and the epee, each of them having different regulations between the events (Gaugler, 2004). The valid target for Epee (the whole body) is much bigger compared to Foil (trunk only) and Sabre (head,trunk,upper arms, and gloves) (Roi & Bianchedi, 2008). Further, Epee is heavier (<770g) compared with Foil and Sabre which share the similar weight (<550g). The blade length for Sabre (105cm) a bit shorter compared with Foil and Epee which share the similar blade length (110cm). The winner is the first fencer to score 5 hits during the preliminary pool bouts or 15 hits should they reach the direct elimination bouts. During the preliminary pools, bouts last for 5 minutes, whereas during elimination, each bout consists of 3 rounds of 3 minutes, with 1-minute rest between the rounds (Turner et al., 2014).

In the women's epee competition, heart rate ranged from 167 to 190 beats/min, i.e. 70% of maximal heart rate, for about 60 % of fight duration (Roi & Bianchedi, 2008). Moreover, Iglesias & Reig (1998) reported that oxygen uptake averaged 39.6 mL/kg/min and 53.9 mL/kg/min for Spanish female and male fencers in competitive bouts. During a regional men's foil competition, blood lactate concentrations assessed 5 minutes after the bout were between 1.4 and 3.9 mmol/L during the preliminary pool bouts of the tournament, meanwhile during the direct elimination bouts and in the finals, blood lactate always higher than 4 mmol/L and the highest value was found in the winner (15.3 mmol/L) at the end of the competition (Cerizza & Roi, 1994).

Average group energetic expenditure during fencing simulation was (mean ± SD) 10.24 ± 0.65 $kcal \cdot min^{-1}$, corresponding to 8.6 ± 0.54 METs (Milia et al., 2013); Oxygen uptake and heart rate were always below the level of anaerobic threshold previously assessed during the preliminary incremental test, while blood lactate reached its maximum value of 6.9 ± 2.1 $mmol \cdot L^{-1}$ during the final recovery minute between rounds. Present data suggest that physical demands in fencing are moderate for skilled fencers and that both aerobic energy metabolism and anaerobic lactic energy sources are moderately recruited. Taken together, all these data emphasize the variability of the physiological response during fencing and the physical demand is affected by different factors, of which age, gender, level of training and the technical and tactical models utilized in relation to the adversary are of importance.

4.3 Athlete Characteristics

Profiles of the athletes will give general information regarding their physical requirements and capabilities in sport combats. Similarities as well as clear differences between the three combat sports in this dissertation will be discussed in the following paragraphs. In line with the methodological approach of the Flemish Sports Compass, we have mainly concentrated on data in the anthropometric, physical fitness, and motor coordination domains of elite combat sport athletes.

Judo athletes should have high physical and physiological fitness to become successful in an international competition (Franchinie et al., 2011). Besides that, Bocioaca (2014) mentioned that technical and tactical aspects of judo athletes are fundamental factors for their success at competitions. This demonstrated that judo athletes need to have a good physical performance with the combination of good technical and tactical skills in order to become successful athletes or to be able to produce winning results in competition. Criteria for the selection of young judo athletes usually include body composition, aerobic power and muscular endurance (Mirzaei, Rahmani-Nia, Lotfi, & Nabati, 2016).

Taekwondo Olympic champions tend to be taller and with lower body mass indices than non-champions (Kazemi, Perri & Soave, 2010; Jakubiak & Saunders, 2008) and the sum of skinfolds was associated with the performance of taekwondo athletes (Sadowski, Gierczuk, Miller, & Cieslinski, 2012). In terms of physical performance, counter movement jump was higher in the elite than the sub-elite athletes, while the performance in squat jump was similar between them (Marković, Misigoj-Duraković & Trninić, 2005).

In fencing, significant differences in most anthropometric measurements were reported between gender for age groups above 14 years old, while there were no significant differences between male and female fencers between the age of 11- 13 years old (Tsolakis, Bogdanis, Vagenas & Dessypris, 2006). Besides that, fencers from an anthropometric point of view were similar regardless of event specialization (Ntai, Zahou, Paradisis, Smirniotou & Tsolakis, 2017). Elite fencers had a higher mean lunge length, larger knee extension and shorter time gap in hand/foot motion compared to the novice fencers (Gholipour, Tabrizi & Farahmand, 2008).

4.3.1 Anthropometry in combat sports

Anthropometry consists of standardized techniques for systematically taking measurements of the body and parts of the body (Malina et al., 2004), In other words, anthropometry is a measurement of the body such as weight, height, lengths of some body segments, skinfold thickness or limbs circumferences. The measurements will use specific tools to get the correct measurements such as stadiometer to measure height, body impendence to measure weight or fat percentage, measuring tape to measure arms spread or using skinfold caliper to measure the skin thickness.

Traditionally, coaches tend to select their athletes according to physical appearances or the body sizes such as length and height. Previous studies (Table 1) show that height and length are important talent characteristics in karate and taekwondo (Ravier et al, 2004; Cesari et al, 2008; Marković et al, 2005; Kazemi et al, 2010). Adult elite karate athletes have longer lower limbs and a lower fat percentage than their peers from other sports (Giampietro et al, 2003; Kazemi et al, 2010). Height and length might be an advantage for combat athletes in order for them to reach their opponent, so that they can score points easily. The body height of judo players is connected with the preferred techniques in combat. Hand techniques are preferred by short and medium-height fighters and leg techniques by tall fighters (Lech, 2007). Earlier work has shown that adult fencers are taller but more slender with wide shoulders and thinner waists (Ochoa, 2013). A typical male fencer is taller and has a higher body mass with longer segment length compared to female fencers (Ntai, Zahou, Paradisis, Smirniotou & Tsolakis, 2017). Those findings shown the relationship between anthropometry and combat in various measurements of anthropometric especially in height, length and weight of combat sport athletes.

More specifically, the average height of elite Judo athletes is between 168cm-186cm (males) and 162cm-167 cm (females). Weight in elite athletes ranges is between 68kg-100.7kg (males) and 56.4kg-74.9kg (females). BMI is usually between 21.4-29.1 kg.m^{-2}, and body fat percentage between 8.1%-15.7 % (Torres-Luque, Hernández-García, Escobar-Molina, Garatachea & Nikolaidis, 2016). Meanwhile, the mean height for elite taekwondo athletes is 183 cm for male and 170cm for female; mean weight for male is 73.4 kg for male and 60.3 kg for female (Kazemi, Waalen, Morgan & White, 2006). The mean body fat percentage is approximately 10 and 15 % for male and female athletes, respectively (Bridge, da Silva Santos, Chaabene, Pieter & Franchini, 2014). Moreover, elite fencer height is between 152cm-184cm (male) and 155cm-167cm (female); Weight measurement is between 46.5kg-74.2kg (male) and 44.4kg-60kg (female): Body fat percentage is between range 19.3-23.6 % (male) and 18.4-22.7% (female) (Roi & Bianchedi, 2008).

Of course, the anthropometric information in the previous paragraphs needs to be considered in the context of weight categories that are used in Judo and Taekwondo, but not in fencing. In general, we can observe the different anthropometric characteristics between the combat sports. Some researchers have identified height as the most significant anthropometric factors contributing to the match outcome in senior national taekwondo athletes (Pieter, Mateo & Bercades, 2002). In the present dissertation we will try to define the relationship between anthropometry and the nature of combat sport, and the level of participation in that sport.

Table 1: Age and main anthropometric information on elite adult combat athletes.

	Age	Height	Weight
Ravier et al., 2004 (Male)	20.1 (1.1)	178.7 (7.8)	71.3 (11.9)
Cesari et al., 2008 (Male)	38.3 (11)	173.1 (5.2)	73.8 (10.7)
Marković et al, 2005 (Female)	21.5 (4.1)	168.0 (6.6)	60.1 (9.0)
Kazemi et al, 2010 (Male)	25.0 (3.53)	183 (0.1)	74.9 (14.7)
(Female)	22.8 (2.8)	168 (0.1)	59.9 (9.4)

4.3.2 Physical Fitness in combat sports

Physical fitness is an essential component in both the identification of the athlete, the evaluation of an athlete's progress (Pearson et al, 2006), and to see the training effect to the athlete. Physical characteristics such as speed, power, strength and endurance are often called as the main components of physical fitness (Caspersen et al, 1985).

Most of the combat sports require a mix of technique, strength, aerobic fitness, power and speed. Generally, there is not one single physical performance characteristic dominates in combat sports, in comparison to some other sports, like marathon running, where the ability to maintain continuous aerobic output dominates (Basset & Howley, 2000). Combinations of various physical factors seem to be an important characteristic in most combat sports like karate, taekwondo and judo. Leg power, core stability, flexibility and balance are the basic requirements for kicking, especially in taekwondo and karate (Ravier et al., 2004; Cesar & Bertucco, 2008; Marković et al., 2005; Kazemi et al., 2010). Explosive strength and agility contribute to faster actions or executed skills in judo, taekwondo and karate (Giampietro et al., 2003; Kazemi et al., 2006; Franchini et al., 2005).

Fencing involves a series of explosive attacks, spaced by low-intensity movements and recovery periods, predominately taxing anaerobic metabolism (Turner et al., 2013). Fencing uses an "on-guard" position in which the Fencer "bounces" in preparation for attack. This position will help the fencer to make a quick transition (defence to attack) or intended action to a new one that can accommodate this. Based on the previous studies, it is clear that a good combination of physical performance components and the mastering the skills or techniques in their particular combat sport is essential.

Previous studies mentioned that elite Judo athlete scored 47.1cm (Tabben et al., 2014), Taekwondo athletes scored 43.2cm (Tabben et al., 2014) and fencing athletes scored 35.47cm (Tsolakis & Vagenas 2010) on the Counter Movement Jump (CMJ) test. For the squat jump, Judo athletes scored 43.9cm (Tabben et al., 2014), Taekwondo athletes scored 39.7cm (Tabben et al., 2014) and fencing athletes scored 31.94cm (Tsolakis & Vagenas 2010).

Moreover, values of Maximal oxygen uptake (VO_2max) has been used as a measure of aerobic capacity and was reported around 50-55 $mL \cdot kg^{-1} \cdot Min^{-1}$ for male and 40-45 $mL \cdot kg^{-1} \cdot Min^{-1}$ for female in Judo (Franchini et al., 2011). The VO_{2max} of senior male and female international taekwondo athletes ranges between 44–63 ml kg^{-1} min^{-1} and 40– 51 ml kg^{-1} min^{-}(Bridge et al., 2014). Meanwhile, the VO_2max mean score for male fencers is 47.0 (Abdollah, Khosrow & Sajad, 2014). In the speed components, Judo elite athletes clocked 4.38s in 30m sprint test, whereas taekwondo athletes clocked 4.33s.

4.3.3 Motor Coordination in combat sport

Although motor coordination is assumed to subserve the learning of motor skills like the techniques in combat sports, it has long been put aside in talent identification research. However, in the past decades this component has gained substantial attention. Motor coordination is defined as a fundamental component of human life (Henderson,1992), expressed in activities such as walking, running, jumping and throwing. Children with low motor competence are less physically active than their better coordinated peers (Stodden et al., 2008) and this situation might avoid them to explore more complex movements that will reduce their potential of movement in their growth development process. Previous studies have discussed the relationship between motor coordination and physical activity as an indicator of physical health (Casperen et al., 1985; Bouchard et al., 1993). Children with lower movement skill levels appeared to have reduce their levels of physical fitness such as flexibility (Cantell et al., 2008), endurance (Haga, 2008, Cantell et al., 2008), strength and speed (Haga, 2008, Cantell et al., 2008). An individual with a lower level of motor coordination will be less active and / or participate to a lesser extent in sport activities, which might have implications for his/her potential career in a specific sport.

Previous studies on the contribution of motor coordination in specific sports such as gymnastic (Vandorpe et al., 2012), soccer (Deprez et al., 2015), skating (Mostaert et al., 2016) and various other sports (Opstoel et al., 2015) have shown that coordination indeed is crucial for participation and development in a specific sport. Kickboxing and taekwondo athletes need a good motor adjustment, movement combining, movement differentiation, time and space orientation, speed of reaction, rhythm and balance (Sadowski, 2005). Judo implies the ability to combine subsequent movements, precise differentiation of movements, subtle variation in the generation of forces, and spatial orientation, quick reaction times, and balance (Manolaki, 1990; Schich, 1979). Similarly, fencers should have good motor adjustment capabilities, spatial oriention, speed of reaction, anticipation and the “feeling of distance” (Sadowski,2005). Most of these characteristics subserve motor coordination, although this terminology is rarely used in the context of talent identification in combat sports, nor have tests been used that claim to measure global motor coordination in this context. From this point of view, the focus on the role of motor coordination in this dissertation could result in valuable additions to our current knowledge of critical characteristics for talent identification in combat sports.

Several researchers have studied the so-called ‘Coordination Motor Abilities’ (CMA), based upon questionnaires and interviews obtained from coaches and specialists in combat sports. The overall relevance of the CMA components in combat sports athletes are summarized in Table 2; Sadowski, (2005). Although this information is interesting, it is derived from personal reports and not from objective measurements. In addition, the practical relevance of this information is not always clear. In general, there is a lack of studies on motor coordination among combat sports using field-based test, especially among the elite athlete. Pion, Fransen, Lenoir & Segers (2014), mentioned the score of motor coordination for under 18 male judo and taekwondo athletes. The study reported that judo athletes and taekwondo scored similarly on a backward balance test; For the Jumping Sideways test taekwondo scored better than judo athletes; Judo athletes and taekwondo athletes scored the same points (68 points) for the Moving Sideways test. Our study will apply the same measurements from Pion et al. (2014) to discover into what extend motor coordination could distinguish combat sport athletes in different level of participations.

Table 2: Dominant CMA in particular combat sports

Type of combat sport	Coordinations Motor Abilities (CMA)
Judo	Precise reproduction of basic movement variables Precise reproduction of basic movement variables, rhythm muscle relaxation Movement combining, precise differentiation of movement, force variables, space orientation Fast and precise reacting, differentiation of movement force variables Movement differentiation, space orientation, balance, speed of reaction, movement combining and adjustment.
Taekwondo	Differentiation of movement variables, space orientation, speed of reaction, movement combining Speed of reaction, space orientation, anticipation movement combining, differentiation of force and space movement variables High movement frequency rhythm speed of reaction, motor adjustment, movement differentiation, space orientation.
Fencing	Movement combining, differentiation of movement variables during unexpected conditions and limited time Motor adjustment, space orientation, speed of reaction, anticipation, the feeling of distance

5.Aims and Hypotheses of This Dissertation

Overall, there is still a lack of information about talent attributes in young combat sport athletes. Therefore, the general aim of this thesis was to expand our knowledge on the profiles of young combat athletes and to explore the applicability of the profiles to predict performance. In the first study, we tested male judo athletes that were under the age of 14 and we categorised them into three groups (elite, sub-elite, drop-out) based upon competitive performance in the years after baseline measurement. From this study, we expected that the groups could have been distinguished based on the three categories of attributes (anthropometry, physical performance, and coordination) and that we could have predicted the performance of young male judo athletes with the use of the predictive statistical models.

In the second study, we measured taekwondo athletes (12 years to 17 years) and categorized them into two groups (elite, non-elite). The aim of this study was to identify the differences between elite and non-elite taekwondo athletes, again based upon competition outcomes. We expected that there would have been differences in anthropometric, physical fitness and motor coordination among the groups.

For the third study, we measured young fencers (11 years to 16 years) and divided them into two groups (medallist, non-medallist). The aim of this study was to identify anthropometric, physical performance and motor coordination characteristics that discriminate between medallist and non-medallist fencers. We expected that there would have been clear differences between medallist and non-medallist young fencers in the three groups of tests.

Finally, the fourth study aimed at identifying children with different profile in terms of physical performance and enjoyment in sport participation and also to define profile differences in organized sports. We measured the actual performances and the level of enjoyment in children aged between 8 years to 11 years old. We expected to identify different combinations of physical performance and enjoyment and that children who are high on both physical performance and enjoyment would also exhibit the highest levels of self-reported sport participation.

Based on the model by Gagné, the Natural Ablilities (sensori motor) could help to define the differences or relationships among athletes in different groups of participation or achievement. A large pool of talented people or groups should increase the quality of talent pool and provide a good talent selection system to define talented young athlete. Entitled to get a bigger number of talented people, we need to make sure a lot of people, especially the youngsters to involved in sport or physical activity. Fun and enjoyment (motivation) is known to be one of the most important motives for children to participate in a sport (Green, 2005; Weiss et al., 2008). We have applied the DMGT (NAT-physical performance) to distinguish combat athletes in different groups (study 1-3) and also applied DMGT (IC-motivation) in the final study to discover the different profile or combination of physical performance and enjoyment among children's sport participation.

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PART 2 : ORIGINAL RESERACH

STUDY 1

Predicting judo champions and medallists using statistical modelling

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Abstract

Background and Study Aim: In the past decade, several studies have convincingly demonstrated that the identification of characteristics in young children can form a solid basis to identify those subjects with the most chance to excel at the international competition level. The present study aims to predict the performance of young male judo athletes with linear and non-linear predictive statistical models. It is hypothesized that a non-sport specific test battery will allocate athletes to their best achievement level at least three years past baseline.

Material and Methods: In this retrospective cross-sectional study, 22 trained male Belgian judo athletes U14 (12.675 ±0.910 years) were tested in 2009-2011 using a generic test battery consisting of five anthropometrical, seven physical performance and three motor coordination tests. In 2016 they were allocated to one of three groups depending on their achievement level between 2013-2015. First, Kruskal-Wallis was used to discover indicators that significantly differ across the three groups sampled by achievements. Second, linear discriminant analysis (LDA) was applied to discriminate the participants and allocate them to their respective achievement level.

Results: The Kruskal-Wallis test showed significant differences for three indicators (sitting height, weight, Body Mass Index). Using all indicators, discriminant analysis correctly classified 95.5% of the participants. Only 36.4% of cross-validated grouped cases were correctly classified based on all indicators. Therefore, a sequential discriminant analysis, containing the significant tests (three indicators) was applied to improve the cross-validated model from 36.4% to 59.1%.

Using all indicators makes the model stronger but using a limited number of indicators makes it easier to assign athletes to the right group.

Conclusions: Generic talent characteristics (anthropometry) included in the present study allow for a successful discrimination between drop out, sub-elite and elite judo athletes. In addition to the trainer's opinion and the individual screening of judo specific performance characteristics, this generic test battery provides opportunities for predicting judo performance of young athletes.

Keywords: cross-sectional study, judo achievements, performance characteristics, talent identification

INTRODUCTION

Today many countries have implied formal talent identification (TID) and talent development (TD) models in the sport to increase their success at the international scene. TID is defined as the process of recognising current participants with the potential to excel in a particular sport, while TD provides the required learning environment to maximise this potential (William & Reilly, 2000; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). Efforts to develop TID and TD models stem from the general conviction that gifted youngsters do not automatically end up at the highest performance level in a particular sport. However, returns from investment on current TID and TD models of sport in youth are sub par, meaning that only a few young athletes continue their career to achieve podium positions at the elite sports level in adulthood (Suppiah, Low & Chia, 2015). Understanding the underlying performance characteristics that relate to international success in judo might help the talent identification (TID) as well as the talent development (TD) process.

In the past decade, several studies have convincingly demonstrated that the identification of characteristics in young children can form a solid basis to identify those subjects with the most chance to excel at the international competition level. Such an approach does not only allow the discrimination between successful and less successful young athletes but also allowed to predict the future performance level to a certain extent. This has been demonstrated in volleyball (Pion, 2015), gymnastics (Pion, 2015; Vandorpe, 2012), soccer, and many other sports (Pion, 2015).

Studies comparing performance characteristics in judo are scarce and are mostly based on the evaluation of judo specific skills and characteristics. Recently Tavra, Franchini and Krstulovic (2016), identified differences between elite and non-elite judo athletes using judo specific tests. The main objective of this study was the discriminant and factorial validity of four judo-specific tests in a sample of high-level junior female judokas. They found that the Special Judo Fitness Test (SJFT) and the Uchi Komi Fitness Test (UFT) better discriminated the elite from the sub elite female judokas. Research using a generic testing battery to reveal performance related characteristics in judo showed that explosive strength, balance, flexibility and agility contribute to faster-executed judo skills (Franchini, Takito, & Kiss, 2005; Krstulovic, Zuvela, & Katic, 2006).

Next, to such sport-specific tests, the importance of general motor coordination has long been neglected in the literature (Vandendriessche et al., 2006; Deprez et al., 2013). Given the technical complexity and speed of execution required in judo, it is assumed that motor coordination also plays an important role in this discipline. The importance of motor coordination has been demonstrated for performance prediction (Pion et al., 2015) as well as for sports orientation. Volleyball players with better results for motor coordination had more chance to reach the podium at international level (Pion et al., 2015a). The same generic test battery showed that it was possible to orient athletes towards different sports (Pion et al., 2015b) as well as to sports that are to a certain extent similar to each other, like martial arts karate, judo and taekwondo (pion et al., 2014). While performance characteristics in judo have been identified in other studies, the retrospective design of this study allows the comparison between judo achievements and baseline performance characteristics at least three years prior to the status of competition participation at the highest level. The pending question is whether predictive models can reduce the talent development costs in judo. It was investigated to what extent judo achievements can be predicted using linear mathematic methods using discriminant analysis.

The present study aims to predict the performance of young male judo athletes with linear and non-linear predictive statistical models. It is hypothesized that a non-sport specific test battery will allocate athletes to their best achievement level at least three years past baseline.

MATERIAL AND METHODS

Participants and design

A sample of 22 highly trained judo athletes (12.675 ±0.910 years) in Belgium participated in this retrospective, cross-sectional study. They were all selected for the Flemish Top Sport Schools, where they were involved in a talent development program preparing them for international competition. This study has been conducted in accordance with recognised ethical standards (Harris & Atkinson, 2015) and was approved by the local Ethics Committee of the Ghent University Hospital. For all participants, written informed parental consent was obtained. None of the participants refused participation.

Measurements

The participants were measured in 2009, 2010 or 2011 and completed five anthropometrical, seven physical performance and three motor coordination tests. A team of experienced examiners of the Department of Movement and Sports Sciences assessed the generic test battery. At any given time, instruction and demonstration were standardised according to the test guidelines. The athletes performed all tests barefoot except the sprints, the counter movement jump and the endurance shuttle run test, which were all performed with running shoes. In 2016, the participants were sought through a reliable data source of judo results at www.judoinside.com. The website provides competition results of judo athletes and their current rankings. Achievements throughout 2013, 2014 and 2015 were registered and categorised by level, i.e. elite, sub-elite or drop out. Athletes who had obtained medals at the national level and/or participated in international tournaments (European and World level) were allocated to the elite category. Meanwhile, athletes who had obtained medals at the national level and/or participated in international tournaments were classified in the sub-elite category. Finally, athletes who had not participated in the national/international competition since 2013, were assigned to the drop out the group.

Anthropometry

Height (H) and sitting height (SH) (0.1 cm, Harpenden, portable Stadiometer, Holtain, UK), body weight (BW) and body fat percentage (BF) (0.1 kg, Tanita, BC-420SMA) were assessed according to previously described procedures (Lohman, Roche & Martorell, 1988) and manufacturer guidelines. Height and weight values were used to calculate Body Mass Index (BMI).

Physical Performance

Flexibility was assessed by the sit-and-reach test of the Eurofit test battery with an accuracy of 0.5 cm (Council of Europe, 1988). To estimate explosive leg power, the counter movement jump was performed. The participants performed three single jumps without arm swing recorded with an OptoJump device (MicroGate, Italy). The highest of three jumps was used for further analysis (0.1 cm). Static strength was measured by the handgrip (Council of Europe, 1988) in Nm. Speed was evaluated by two maximal sprints of 30 meters with split time measured at five meters. The recovery time between each sprint was set at two minutes. The fastest time for the 5m sprint and 30m sprint was used for analysis (Matthys et al., 2011). The sprint tests were recorded with MicroGate Racetime2 chronometry and Polifemo Light photocells at an accuracy of 0.001 s (MicroGate, Italy). Upper body strength was determined by the performance of sit-ups according to the BOT2 procedures (Bruininks & Bruininks, 2016), requiring the athletes to execute as many repetitions as possible in 30 seconds. The beep test, with the final 30 seconds that persisted (0.5 min), was used for valuing the endurance of the participants.

Motor Coordination

Gross motor coordination was evaluated using three subtests of the “KörperkoordinationsTest für Kinder” (KTK) (Kiphard & Schilling, 2007; Lenoir et al., 2014). The fourth test hoping for height was not performed, due to the risk of injuries to the ankles (Prätorius & Milani, 2004). First, participants had to walk backwards along balance beams of decreasing width (6 cm; 4.5 cm and 3 cm respectively). Secondly, participants had to jumping sideways with a two-legged, performed over a wooden slat (2 x 15 s), summing the number of jumps over the two trials.

Thirdly, participants had to move sideways on wooden platforms (2 x 20 s), summing the number of relocations over two trials.

Performance Level

All competition results were sought by the year 2013, 2014 or 2015 in the database at www.judoinside.com, a trusted source for judo results since 2002. Athletes classified as ‘drop out’ have not participated in the national/international competition since 2013. Sub-elite athletes were those who won a medal at national championships or international tournaments in National Cadets Championship (NCAD) and National Juniors Championship (NJUN), or International Cadets Tournament (ITCAD) and International Juniors Tournament (ITJUN).

Elite judo athletes outstand the other ones by participating or winning a medal in European or World Cups and Championships in International Judo Federation (IJF), World Tour for Cadets (IJFCAD), International Judo Federation (IJF) World Tour for Juniors (IJFJUN), European Cadet Championships (ECHCAD) or World Cadet Championships (WCAD). The best achievement of that year was registered and based on their best achievement through all three years (2013, 2014 and 2015) the judo athletes were grouped in their corresponding class.

Statistical analyses

All data were analysed using SPPS for Windows version 23.0. The present study had a cross-sectional design involving three study groups: drop out, sub-elite and elite. The basic descriptive indicators (mean and standard deviation) were calculated for all analysed variables. The Kolmogorov Smirnov test revealed that some of the variables were not normally distributed ($p<0.05$). Consequently, the non-parametric Kruskal-Wallis Test was used to compare all test results across the 3 groups. Second, a discriminant analysis was used to investigate for relevant achievements in this sample of young male judo athletes U14. In this analysis, belonging to either of three levels was the grouping variable, and the independent variables were the test results obtained from the five anthropometrical characteristics, seven physical characteristics and three motor coordination tests. Third, a Sequential Canonical Discriminant Analysis was used to examine the test that showed to be significant across the three groups to improve the cross validated the model.

RESULTS

From the initial 22 judo athletes, six were categorised as elite athletes or champions based upon their best achievements at European and world level three years after baseline tests. Ten judo athletes participated in international tournaments in 2013-2015 and were called sub-elite athletes or medallists. Six of them were considered as drop out since they did not participate in the national/international competition since 2013. The elite group performed better than the sub-elites and dropped outs in most of the physical performances test. They seem to perform better in 5m sprint test, 30m sprint test, sit and reach test, sit up test and beep test compared to the other two groups (Table 1).

Table 1. Mean and standard deviations from the descriptive analysis for male judo athletes U14 in three different groups.

Variable (indicator)	**Evaluated group**		
	elite **n = 6**	**sub-elite** **n =10**	**drop-out** **n = 6**
Age (year)	13.0 (±0.5)	12.5 (±1.1)	12.7 (±0.9)
Height (cm)	153.9 (±6.0)	150.0 (±7.2)	156.6 (±11.8)
Sitting height (cm)*	82.5 (±5.4)	77.0 (±3.9)	82.9 (±5.4)
Weight (kg)*	47.5 (±5.9)	39.3 (±5.9)	51.1 (±12.2)
Fat percentage (%)	13.5 (±1.9)	12.2 (±2.9)	16.2 (±4.5)
BMI*	20.0 (±1.3)	17.4 (±1.5)	20.6 (±2.9)
Sprint 5m (s)	1.17 (±0.07)	1.28 (±0.1)	1.23 (±0.14)
Sprint 30m (s)	4.98 (±0.2)	5.34 (±0.29)	5.09 (±0.66)
Hand grip (Nm)	30 (±6)	23 (±7)	30 (±16)
Sit and reach (cm)	24.8 (±8.1)	21.5 (±5.5)	21.1 (±3.4)
Counter movement jump (cm)	27.4 (±1.7)	24.6 (±4.3)	27.5 (±6.7)
Sit up (repetitions/30s)	46 (±7)	41 (±6)	41 (±5)
Beep Test	9.7 (±1.5)	8.9 (±1.7)	8.4 (±2.2)
Balance beam (points)	59 (±11)	56 (±8)	54 (±9)
Jumping sideways (points)	97 (±10)	98 (±14)	96 (±12)
Moving sideways (points)	67 (±8)	61 (±10)	59 (±9)

Some of the generic performance tests were not normally distributed ($p<0.05$) and therefore, non-parametric tests applied for statistical analysis (based on Kolmogorov Smirnov test of normality with Lilliefors correction normally distributed). The distribution of Z-scores for sitting height ($p = 0.021$), weight ($p = 0.025$) and BMI ($p = 0.020$) was significantly different across the groups. No other significant differences found in this analysis (Table 2).

Discriminant analysis (DA) applied on all tests as predictor variables revealed two significant functions FD1 and FD2 in the sample of trained male judo athletes U14 athletes. Almost all athletes (95.5%) were correctly classified in their respective achievement level ($df = 30$; $r_{can} = 0.887$; Wilks' $\Lambda = 0.08$ and $p<0421$). However, only 36.4% of cross-validated grouped cases were correctly classified. Figure 1 illustrates the differences between the achievement levels for trained male athletes U14 based on canonical discriminant functions calculated from all the predictor variables.

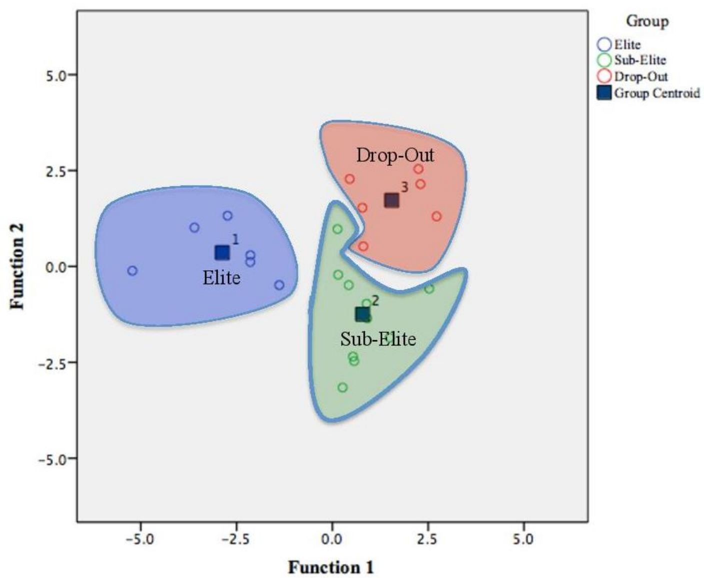

Figure 1. Differences across 3 group for male judo athletes U14, based on canonical discriminant function calculated from the 15 generic tests.

Table 2. Mean and standard deviations from Z-Score for male judo athletes U14 in three different group.

Variable (indicator)	**Evaluated group**		
	elite **n = 6**	**sub-elite** **n =10**	**drop-out** **n = 6**
Height (cm)	0.13 (±0.71)	−0.34 (±0.84)	0.44 (±1.39)
Sitting height (cm)*	0.44 (±1.00)	−0.58 (±0.72)	0.52 (±1.01)
Weight (kg)*	0.29 (±0.64)	−0.59 (±0.63)	0.68 (±1.31)
Fat percentage (%)	−0.04 (±0.55)	−0.41 (±0.82)	0.73 (±1.30)
BMI*	0.42 (±0.57)	−0.67 (±0.62)	0.70 (±1.21)
Sprint 5m (s)	−0.58 (±0.62)	0.37 (±0.92)	−0.03 (±1.27)
Sprint 30m (s)	−0.46 (±0.48)	0.40 (±0.69)	−0.21 (±1.58)

Hand grip (Nm)	0.33 (±0.59)	−0.40 (±0.67)	0.33 (±1.57)
Sit and reach (cm)	0.43 (±1.40)	−0.13 (±0.94)	−0.21 (±0.58)
Counter movement jump (cm)	0.27 (±0.37)	−0.34 (±0.92)	0.30 (±1.45)
Sit up (repetitions/30s)	0.59 (±1.11)	−0.23 (±0.99)	−0.21 (±0.78)
Beep Test	0.40 (±0.84)	−0.06 (±0.94)	−0.31 (±1.26)
Balance beam (points)	0.33 (±1.20)	−0.02 (±0.91)	−0.30 (±1.01)
Jumping sideways (points)	−0.02 (±0.86)	0.06 (±1.18)	−0.09 (±0.97)
Moving sideways (points)	0.55 (±0.83)	−0.10 (±1.09)	−0.37 (±0.91)

*p<0.03

A way to improve the cross-validation of the model is to take into account the significant indicators and therefore a sequential discriminant analysis (SDA) was applied on the three significant tests, i.e. sitting height, body weight and stature. The SDA classified 72.7% of the judo athletes in the correct group when using the achievement level as a grouping variable (df = 6; rcan = 0.690; Wilks' $\Lambda = 0.481$ and $p<0.04$). More important is that 59.1% of cross-validated grouped cases correctly classified with this model.

DISCUSSION

This retrospective cross-sectional study investigated to what extent boys U14 in judo could be predicted as future champions or medallists by means of a generic test battery. The main finding was that the test battery, which contained five anthropometric, seven physical performance and three motor coordination tests allocated 95.5% of the participants in the correct group. However, this model showed to be not strong enough to allocate new participants since the cross-validation using the leave-one-out method classified only 36.4% of the participants in the correct group. Therefore, a sequential discriminant analysis was performed with the significant tests, i.e. sitting height, weight and BMI. Discriminant analysis showed 72.7% successful discrimination in their respective achievement level three years later. Based on the descriptive analysis, this study shows that elite- and sub-elite athletes are much lighter than the drop out. Compared to the sub-elites and drop out, the elite athletes seem to show better results in 5m sprint test, 30m sprint test, sit-and-reach test, sit ups and beep test. Besides the physical characteristics, it can be expected that the better athletes outperform the drop out for motor coordination based on the descriptive analysis.

Nevertheless, the discriminant analysis shows no significant difference between those three groups in motor coordination. One might conclude that motor coordination might not be an important factor in determining who makes it into an elite level in judo and who does not. However, general motor coordination has been proven a valuable indicator of an athlete's potential for progression and as such an important talent characteristic in skill-based sports such as artistic gymnastics (Vandorpe et al., 2012) and combat sports (Sadowski, 2005). Pion and colleagues (2014) applied a generic test battery to discriminate three martial arts and found that the physical and the motor performance tests significantly differed for the three sports and that the anthropometrical indicators were not significantly different between judo, karate and taekwondo. In contrast to our findings, Krstulovic and colleagues (2006) reported that motor coordination and balance is better developed in elite judo compared to non-elite. Therefore, specific assessment tests would be of importance for success in judo competitions (Pocecco et al., 2012).

Pocecco et al., (2012) also reported that judo performance, i.e. the rank in judo competitions, of adult men was negatively related to fat percentage and positively related to relative Pmax of the upper body. According to Franchini et al. (2011), dynamic grip strength endurance seems to be a discriminating variable between judo athletes, probably because judo combat involves many elbow extensions and flexions to avoid the opponent's grip and to subdue them. The differences in the current study with the literature might be explained on the one hand by the fact that our sample size is limited. On the other hand, compared with the scores in the study of Pion et al. (2015b) on young, different sports athletes, it is remarkable that the scores of the current sample are much better in general. This indicates that this sample might already have been pre-selected and therefore are more homogeneous with respect to motor coordination.

Considering the specificity of judo, it becomes necessary to evaluate performance using specific methods and characteristics from a certain performance level on. The Special Judo Fitness Test (SJFT) training method (Sterkowicz, 1995) is one of the most utilised tests in this context; a considerable number of national teams use the test to evaluate the physical capacity relevant to judo (Franchini et al. (2009). Franchini and colleagues (2011) affirm that the SJFT is valid in relation to the physiological demands imposed by the judo fight. Boguszewski et al. (2006) analysed indices of struggle dynamics by male and female (seven each) finalists from European Championships in Rotterdam 2005. They concluded that the gold medallists exhibited a markedly higher struggle dynamics in mean effective offensive actions (EA), effective counter attacks (EC) and global index of struggle dynamics (SDI) values than their opponents. Talent identification is a complex phenomenon and requires a new specialisation – talent scout – both from judo coaches, as well as researchers science of martial arts.

Strengths and Limitations

The strengths of this study are the use of a combination of anthropometrical, physical performance characteristics and motor coordination tests. This study applied linear predictive models with generic tests for allocating judo champions. The prediction based on generic tests in a three years retrospective study is a new approach to talent identification and talent development in judo. The limitation of the relatively small sample size is inherent to research in trained athletes, who are not numerous by definition. For further research of this type, a bigger sample size is strongly recommended especially given the difference in weight categories. Only those who managed to participate in international competitions, European or World Championships can belong to the elite class of judo in Belgium. During the talent development phase between testing (2009-2011) and achievement years (2013-2015), there could be other factors than just those anthropometrical and physical characteristics or motor coordination influencing the achievement. In this grey zone, a lot can happen to overestimate or underestimate the young judo athletes, for example, the development of athletes can be influenced by illness or injuries.

CONCLUSIONS

Generic talent characteristics (anthropometry) included in the present study allow for a successful discrimination between drop out, sub-elite and elite judo athletes. In addition to the trainer's opinion and the individual screening of judo specific performance characteristics, this generic test battery provides opportunities for predicting judo performance of young athletes.

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Study 2

Identification of elite performance characteristics in a small sample of taekwondo athletes

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ABSTRACT

Background and Study Aim:

Along with the increasing popularity of taekwondo, there is a need of evidence-based talent identification (TID) and development programs based upon profiles of future elite athletes. This study first aims to investigate the differences between elite and non-elite taekwondo athletes in anthropometry, physical performance and motor coordination. The second aim is to demonstrate the applicability of z-scores in TID research.

Material and Methods: A total of 98 Taekwondo athletes between 12 and 17 years old were tested using a generic test battery consisting of four anthropometrical (Height,Weight, Fat Percentage, BMI), six physical performance (Sit & Reach, Sprint 5m, Sprint 30m, Counter Movement Jump, Squat Jump, Endurance Shuttle Run) and three motor coordination tests (Moving Sideways, Jumping Sideways, Walking Backwards). Based on the individual success at international competition level, 18 were categorised as elite athletes and 80 were considered as non-elite.

T-tests (step 1) on raw test scores and MANOVAs on z-scores (step 2) were conducted to examine differences between the elite and non-elite taekwondo athletes for anthropometry, physical performance and motor coordination tests. Finally, z-scores were reconverted to raw scores to demonstrate practical significance for coaches.

Results: Overall, elite taekwondo athletes score better compared to the non-elite group. The MANOVA analysis better scores for elites on fat percentage (-0.55 versus 0.12;p=0.006), BMI (-0.37 versus 0,08;p=0.067) sprint speed 30m (-0.48 versus 0.11;p=0.029), counter movement jump (0.79 versus -0.18;p=0.000), squat jump (0.42 versus -0.11;p=0.041), moving sideways (0.79 versus -0.18;p=0.000) and walking backwards (0.54 versus -0.12;p=0.006).

Conclusions: This study confirms our knowledge on physical profiles of elite taekwondo athletes and expands our knowledge to the domain of motor coordination. This study showed

how the z-score method can be used to distinguish between elite and non-elite athletes, the former being low in number by definition.
Keywords: Performance, Tests, Motor Coordination, Achievements

INTRODUCTION

Combat sports like fencing, judo, taekwondo, and many others have become more popular in the past decades, with increasing number of participants around the world [1]. Along with this increased popularity, coaches and federations are in need of evidence-based talent identification and development programs. The key question in talent identification is to decide which athlete has the most potential to perform well and be successful at the highest competitive level [2]. Resources for the development of young talented athletes are limited and yet most federations are expected to provide a return on investment in the talent identification process [3]. Extensive knowledge on characteristics of combat athletes of different ages and performance levels are therefore crucial. In the past decades, profiles of athletes active at various levels of participation and in different disciplines of combat sports like wrestling [4], judo [5,6], taekwondo [6,7] and fencing [8] have been partially documented.

Taekwondo has been a part of the Olympic demonstration program since Seoul 1988 and Barcelona 1992, before becoming an Olympic discipline from the Sydney 2000 Olympic Games. In this paper we focus on the anthropometric, physical, and coordinative profiles of taekwondo athletes of different levels. Taekwondo is a full contact free-sparring sport, which consists of punches and kicks that have to produce a displacement of the body segment of the opponent. The words ‘Taekwondo’ translates as tae to hit using the foot (kick), kwon to hit using the fist (punch) and do referring to the art [9]. It is a native Korean fighting art that originated thousands of years ago and has become a popular sport with over 120 million children and adults actively participating worldwide [1]. Taekwondo consists of 3 x 2-minute rounds with a 1-minute rest period between each round. Points are awarded for body and head contacts, matches are won via knockout or via higher point score.

The identification and selection of elite athletes is a complex process affected by several factors that vary in relation to the specific nature of the sport discipline. With respect to body height, lengths between 170 cm [10] and 183 cm [7] for adult male elite athletes are reported, however accompanied by relatively high standard deviations. Body weights range significantly between 60 and 75 kg in males and between 47 and 59 kg in female adult athletes. This large variability is at least partially related to the weight categories in taekwondo, but also within a weight category athlete of different lengths can excel. With respect to BMI and fat percentage, BMI around 21 kg/m^2 and fat percentage around 10% for males appear to be associated with elite performance [11].

With respect to physical performance, taekwondo requires athletes to dispose of explosive leg power, and flexibility because of the emphasis on kicking [12,13,14,15,16]. Taekwondo is renowned for its swift kicks and dynamic footwork. One of the most popular used skills is roundhouse kick [15] also known as Dollyo Chagi [17] in Korean language, and other common techniques include side kick (Yop Chagi), back kick (Momdollyo Chagi) and spinning kick (Dolmyo Chagi) [16,17]. In taekwondo, specific indications of leg power derive from assessments of jumping and sprinting activities that are necessary to generate powerful kicks [12,13] and counter-movement jump (CMJ) performances have been used to evaluate leg power [18]. Leg power seems to be an important factor for proper execution of techniques while kicking or performs footwork during competition and might an indicator to distinguish between the elite and sub-elite. Lower limb explosivity is usually evaluated by means of the CMJ, in which values close to or above 40 cm are attained in males [11]. Taekwondo athletes with good lower limb explosivity will produce more power during kicking and this will give them advantages during competition.

Taekwondo belongs to a group of sports in which speed of execution plays a key role in achieving success [7,19]. The speed of taekwondo has been examined using field-test methods, including 20m sprint [15], 30m sprint [20] and 6s sprint tests [21]. Limited data from previous studies demonstrate that successful male taekwondo juniors record 4.62s (medallists) and 4.81s (non-medallist) in 30m sprint test [20]. Similarly, female medallist can run 20m in 3.6s on average, versus 3.81s for non-medallists [15]. Altogether, with respect to physical characteristics it appears that the combination of excellent speed and power values will be a great advantage for taekwondo athletes and enable the discrimination of taekwondo athletes of different competition levels.

While the morphological and physical profile of taekwondo athletes are well documented, motor coordination is virtually absent in this literature. Nevertheless, the technical requirements of taekwondo skills are high, and these skills need to be executed under severe time pressure. While the qualitative evaluation of skill execution is sometimes used in talent identification, those results are strongly affected by training history, and thus do not allow a clear evaluation of an athlete’s potential to excel in the future. Recent studies have shown that general, non-sportspecific motor coordination tests can distinguish between athletes in different sports and levels of participation, and even allow the prediction of future performance [21]. The underlying idea is that an excellent coordination facilitates the acquisition of new and complex techniques. Differences in motor coordination between athletes of different levels have been found in previous studies. Pion et al. (2015) [22], demonstrated that a general motor coordination test was a stronger predictor of future performance in female elite volleyball players compared to physical test scores or specific volleyball skills like jumping and overhead throwing actions. This also indicates that non-sport specific sport test (motor coordination) should also be taken into account in detecting talented young athletes. In spite of the potential significance of coordination tests, virtually none of the studies available reports on this aspect so far in combat sports.

Information on anthropometric, physical performance and motor coordination profiles of elite level athletes is beneficial to coaches or teachers as it can be used as a reference to planning athlete training programmes and distinguishing their athletes in accordance to their data. Although these characteristics are not the only determinants of success, they do serve to provide additional input for coaches and may aid in optimizing their athlete's potential. While literature already provides a clear picture of anthropometric and physical profiles of elite athletes, most of them are dominantly descriptive in nature. Only a few studies have focused on the comparison between elite and sub-elite athletes, and most of them do not take into account motor coordination. Therefore, this study aims to investigate the differences between elite and non-elite taekwondo athletes in anthropometry, physical performance and motor coordination. Building upon the international success of the Belgian Taekwondo athletes, the aim of this study is to identify the generic, that is, non-sport specific characteristics associated with high performance level.

In addition, this study aims at demonstrating the applicability of z-scores in TID research. The number of elite youth athletes is limited by definition, and profiles might be confounded by differences in age and gender. Conversion into z-scores based upon on external reference population might be at least partially resolve this issue.

MATERIAL AND METHODS

Participants and design

The data for this study is part of the Flemish Sport Compass (FSC), a project that began in 2007 and is still on-going [23,24,25,26]. Out of a sample of 98 Taekwondo athletes age measured between 12 to 17-year-old, 18 were categorised as elite athletes based on their performance level as senior. Elites were a member of the Belgian national team (representing Belgium at international championships or at the Olympic games) and/or had won at least one medal at an international taekwondo competition. A total of 80 taekwondo athletes were considered as non-elite since they were not in the elite squad and did not participate or did not win medals in an international championship (Table 1). This study has been conducted in accordance with recognized ethical standards [27] and was approved by the local Ethics Committee of the Ghent University Hospital [28]. For all participants, written informed parental consent was obtained. None of the participants refused participation.

Table 1: Demographic Information of The Elite and Non-Elite Taekwondo Athletes.

Age Group (years)	**Elite**		**Non Elite**		**Total**
	Male	**Female**	**Male**	**Female**	
12	1	1	8	2	12
13	1	1	7	6	15
14	3	2	10	10	25
15	2	2	7	12	23
16	1	2	10	3	16
17	1	1	1	4	7
Total	9	9	43	37	98

Measurements

The athletes were measured between 2008-2016 and completed four anthropometrical, six physical performance and three motor coordination tests. A team of experienced examiners from the Department of Movement and Sports Sciences assessed the generic, i.e. not containing sport specific tests, battery. At any given time, instruction and demonstration were standardized according to the test guidelines [29]. The athletes performed all tests barefoot with the exception of the sprints, the counter movement jump, and the endurance shuttle run test, which were all performed with running shoes.

Anthropometry

Body height was measured using a calibrated stadiometer (0.1 cm, Harpenden, portable Stadiometer, Holtain, UK). In addition, body weight and body fat percentage were assessed using a digital balance scale with a foot-to-foot bioelectrical impendence system (0.1 kg, Tanita, BC-420SMA) according to previously described procedures [27] and manufacturer guidelines. Body height and body weight values were used to calculate Body Mass Index (BMI in kg/m^2). In addition, sitting height was measured to calculate the Age of Peak Height Velocity (APHV) as a measure of biological maturation [30,31].

Physical Performance

Flexibility was assessed by the sit-and-reach test of the Eurofit test battery with an accuracy of 0.5 cm [25]. Speed was evaluated by two maximal sprints of 30 meters with split time measured at 5 meters. The recovery time between each sprint was set at two minutes. The fastest time for the 5m sprint and 30m sprint was used for analysis [32]. The counter movement jump (CMJ) and the squat jump were performed to estimate explosive leg power. The athletes performed three single jumps without arm swing recorded with an OptoJump device (MicroGate, Italy) and the highest of three jumps was used for further analysis (0.1 cm). Finally, the cardiorespiratory endurance was measured using the endurance shuttle run test (Beep test) with an accuracy of 0.5 min [25].

Motor Coordination

Gross motor coordination was evaluated by the short form of the "KörperkoordinationsTest für Kinder" (KTK) [29]. First, participants had to walk backwards along balance beams of decreasing width (6 cm; 4.5 cm and 3 cm respectively). Secondly, participants had to perform two-legged jumps sideways over a wooden slat (2 x 15 s), summing the number of jumps over the two trials. Thirdly, participants had to move sideways on wooden platforms (2 x 20 s), summing the number of relocations over two trials. This test has been shown to allow discrimination between combat athletes of different disciplines in previous studies [6].

Statistical analyses

Data was analysed using SPPS for Windows version 25.0. The present study had a cross-sectional design, involving two study groups: elite and non-elite. The basic descriptive indicators (mean and standard deviation) were calculated for all analysed variables given that most of the variables were normally distributed and thus met the conditions of parametric analysis. Given the relatively low number of athletes in the elite group, which is an inherent characteristic of research in elite athletes, a three-step analysis was used. First, a t-test was applied to compare anthropometry, physical performance, and motor coordination between elites and sub-elites. Mean scores and statistical results are presented in Table 2.

Table 2: Data for The Counter Movement Jump for Boys in The Elite Sport Schools [23]

Age (years)	N	Minimum (cm)	Maximum (cm)	Mean (cm)	SD (cm)
12	48	18.80	38.85	27.53	4.30
13	60	17.60	38.00	27.78	4.21
14	74	19.42	51.63	31.68	5.30
15	74	23.2	54.70	34.84	5.44
16	82	24.38	51.36	35.79	5.87
17	87	25.8	56.51	37.81	6.55

The data based on the CMJ score from the Flemish Top Sport School athlete in gymnastic, skating, soccer, athletics, badminton, basketball, handball, judo, fencing, taekwondo, table tennis, triathlon, tennis, golf, volleyball, swimming, cycling, ski.

Overall, gender and age were equally distributed over both groups (see Table 1), although not for each age group separately, the analysis above is limited in that it does not take into account these factors. To allow the comparison of the results of taekwondo athletes from different age and gender groups, standardized z-scores (i.e. the difference between an individual score from the mean, divided by the standard deviation of the sample) [33] were calculated for each of the 13 variables in the second step. To this end a large reference database of 699 young, well-trained athletes in 18 sport disciplines from the Flemish Top Sport Schools of which the same measurements were available was used [23]. For example, the score on the sprint of a 12-year old male taekwondo athlete was converted into a z-score based upon all 12-year old male athletes in the Flemish Top Sport Schools, resulting in a gender- and age-neutral score. In this way, the statistical issue of low sample sizes that is inherently related to research in individual elite athletes was avoided.

Z-scores are however an abstract concept that is often not very informative neither of great practical applicability for coaches. Therefore in a third step, the obtained z-scores were reverse calculated in order to obtain the average value a taekwondo elite athlete (male or female) between 12 and 17 years should obtain. For example, table 2 shows the mean and average scores of the counter movement jump in boys between 12 and 17 years of age from the reference population. A z-score of +1 is then equal to 27.53 + 4.30 = 31.83 cm for a 12-year old well-trained male individual. In addition, ROC analyses were performed to evaluate the discriminative power of each test separately. A high area under the curve (AUC) reflects a better discrimination of elites versus sub-elites with a given test [34].

The magnitude of the differences between the levels was estimated using Partial Eta Squared with cut-off of 0.01 (small), 0.06 (moderate) and 0.14 (large) [23]. The level of significance was set at $p<0.05$.

RESULTS

Anthropometry

Table 3 shows the raw scores and the t-test results of the anthropometric measurements height, weight, fat percentage and body mass index in elite and non-elite athletes. The absolute values indicate that elite athletes tend to be taller and leaner compared to non-elites. The t-test results also indicate a significant difference between elite and non-elite in fat percentage as shown in Table 3. However, statistical analysis of the z-scores led to lower values in fat percentage and boarder-line lower BMI values only (Table 4). AUC for fat percentage and BMI were 0.71 and 0.74, respectively, indicating high discriminative power.

Physical performance

Descriptive data (Table 3) show that elite taekwondo athletes score better than non-elite group in all of the physical performance tests. There are significant differences in t-test results for sprint 30m, counter movement jump and squat jump test (Table 3). The higher physical performance scores in Table 4 are reflected in significant overall effect in physical performance ($p<0.006$). Using the z-score data (Table 4), MANOVA analysis on z-scores show significant differences in physical performance more specifically in the sprint 30 m, counter movement jump and squat jump test. AUCs for these tests were 0.68, 0.82, and 0.70, respectively.

Motor Coordination

Raw scores on motor coordination means appear to be higher in the elite group compared to the non-elite group (Table 3). However, the three general motor coordination tests show significant differences in the t-test results (Table 3). This observation was confirmed by the MANOVA analysis (Table 4) on the z-scores showing significantly better scores for elite athletes in two out of three general motor coordination tests. AUC was 0.80 for moving sideways and 0.71 for the balance beam.

In Table 5, the z-scores obtained from the 18 elite taekwondo athletes have been reconverted into raw performance scores on each test, for male and female athletes between 12 and 17 years of age. For example, a z-score of 0.21 for length which is indicative for elite taekwondo athletes in general, equals 158.38 cm in 12 years old male taekwondo athletes, a figure that rises up to 180.88 cm at the age of 17.

Table 3: Mean and Standard Deviations (Sd) from The Descriptive Analysis, T-Test Results and Levene's Test for Elite and Non-Elite Taekwondo Athletes.

Measurement	Mean (SD)		t-Test result		Levene's Test
	Elite	Non-Elite	t	p	p
Anthropometry					
Height (cm)	166.7 (8.28)	163.4 (10.49)	1.28	0.20	0.18
Weight (kg)	51.3 (9.00)	51.9 (10.64)	-0.19	0.85	0.42
Fat Percentage (%) *	11.9 (3.65)	15.12 (6.55)	-2.01*	0.05	0.00
BMI (kg/m^2)	18.3 (1.78)	19.3 (2.38)	-1.59	0.12	1.22
Physical Performance					
Sit & Reach (cm)	32.5 (6.29)	30.1 (7.87)	1.22	0.23	4.22
Sprint 5m (s)	1.16 (0.08)	1.19 (0.09)	-1.59	0.12	0.72
Sprint 30m (s) *	4.72 (0.33)	4.92 (0.37)	-2.11*	0.04	0.66
Counter Movement Jump (cm) **	33.4 (4.95)	28.4 (5.62)	3.50**	0.00	0.84
Squat Jump (cm) *	30.1 (6.45)	26.4 (5.19)	2.49*	0.02	0.47
Endurance Shuttle Run (min)	10.3 (2.01)	9.5 (1.69)	1.83	0.07	0.84
Motor Coordination					
KTK Moving Sideways (n/2*20s) **	73.9 (8.96)	63.8 (9.46)	4.12**	0.00	0.92
KTK Jumping Sideways (n/2*15s) *	112.7 (10.18)	105.8 (12.88)	2.14*	0.04	0.07
KTK Walking Backwards (n) **	65.1 (6.93)	55.8 (12.69)	3.00**	0.00	0.01

**indicates a significant difference between groups ($p<0.01$), *indicates a trend towards significant ($p<0.05$).

Table 4: Means (SD) and Statistics of Z-Scores on Anthropometric, Physical Performance and Motor Coordination Tests of Elite and Non-Elite Taekwondo Athletes.

Measurement	Z-Score (SD)		MANOVA		Partial Eta Squared	Covariate (APHV)		MANCOVA (APHV)	
	Elite	Non Elite	F	p		F	P	F	p
Anthropometric			**2.872***	**0.027**	**0.11**	**6.913****	**0.000**	**2.789***	**0.031**
Height	0.21 (0.79)	-0.05 (0.97)	1.075	0.302	0.02	23.061**	0.000	0.607	0.438
Weight	-0.08 (0.89)	0.02 (0.96)	0.166	0.684	0.00	24.007**	0.000	0.685	0.410
Fat Percentage	-0.55 (0.98)	0.12 (0.89)	7.928**	0.006	0.11	4.798*	0.031	9.181**	0.003
BMI	-0.37 (0.85)	0.08 (0.95)	3.440	0.067	0.05	6.437*	0.013	4.389*	0.039
Physical Performance			**3.331****	**0.006**	**0.22**	**1.178**	**0.198**	**3.411****	**0.005**
Sit & Reach	0,26 (0.78)	-0.05 (0.97)	1.694	0.197	0.02	0.532	0.468	1.536	0.219
Sprint 5m	-0.32 (0.87)	0.07 (0.95)	2.889	0.093	0.04	0.762	0.386	3.100	0.082
Sprint 30m	-0.48 (0.91)	0.11 (0.92)	4.963*	0.029	0.06	0.819	0.368	4.628*	0.035
Counter Movement Jump	0.79 (0.73)	-0.18 (0.89)	18.340**	0.000	0.19	0.044	0.835	18.144**	0.000
Squat Jump	0.42 (0.92)	-0.11 (0.92)	4.318*	0.041	0.05	0.578	0.450	4.508*	0.037
Endurance Shuttle Run	0.39 (0.99)	-0.09 (0.91)	2.755	0.101	0.04	1.508	0.223	3.071	0.084
Motor Coordination			**7.207****	**0.000**	**0.19**	**0.754**	**0.523**	**7.343****	**0.000**
KTK Moving Sideways	0.79 (0.74)	-0.18 (0.89)	18.790**	0.000	0.18	0.834	0.363	19.229**	0.000
KTK Jumping Sideways	0.34 (0.78)	-0.08 (0.96)	2.957	0.089	0.03	1.865	0.175	3.314	0.072
KTK Walking Backwards	0.54 (0.66)	-0.12 (0.96)	7.951**	0.006	0.08	1.011	0.317	8.321**	0.005

** indicates a significant difference between groups (p<0.01), *indicates a trend towards significant (p<0.05).

Table 5: Converted from z score to raw score (New Score)

Age		12		13		14		15		16		17	
	TKD z-score	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Anthropometry													
Height (cm)	0.21	158.38	158.40	161.84	163.19	173.53	168.24	179.82	167.59	180.77	170.97	180.88	170.86
Weight (kg)	-0.08	42.63	42.84	46.18	47.33	56.01	54.10	63.16	56.76	66.25	58.11	69.68	60.16
Fat Percentage (%)	-0.55	10.74	15.73	9.75	16.27	9.13	18.62	9.11	20.29	9.21	20.06	9.36	20.78
BMI (kg/m²)	-0.37	17.03	16.83	17.42	17.70	18.55	18.96	19.50	19.95	20.23	19.97	21.08	20.52
Physical Performance													
Sit & Reach (cm)	0.26	25.13	28.23	23.75	31.21	25.82	32.93	28.04	34.21	27.00	33.65	31.27	33.34
Sprint 5m (s)	-0.32	1.21	1.22	1.18	1.19	1.12	1.19	1.09	1.17	1.08	1.14	1.07	1.19
Sprint 30m (s)	-0.48	4.93	5.03	4.84	4.83	4.60	4.82	4.41	4.76	4.34	4.66	4.27	4.77
Counter Movement Jump (cm)	0.79	30.94	28.73	31.11	31.97	35.87	30.68	43.14	32.16	40.43	32.83	42.98	32.93
Endurance Shuttle Run (min)	0.39	10.22	9.42	10.59	9.74	11.47	10.47	12.22	10.12	12.28	9.92	12.87	10.35
Motor Coordination													
KTK Moving Sideways (n/2*20s)	0.79	63.83	64.39	65.21	69.06	68.18	70.49	72.36	71.10	74.19	72.28	75.47	71.59
KTK Jumping Sideways (n/2*15s)	0.34	91.92	89.84	93.01	92.34	96.40	97.77	100.23	98.23	101.64	96.61	104.73	98.63
KTK Walking Backwards (n)	0.54	64.82	64.69	70.97	66.60	61.78	65.05	64.83	66.98	64.68	67.88	67.87	67.04

DISCUSSION

This cross-sectional study was designed to investigate differences in anthropometry, physical performance level, and motor coordination between elite and non-elite taekwondo athletes. Apart from providing reference values in taekwondo athletes, the main finding of this study is that the medal winners in international competitions can be distinguished from sub-elite peers based upon morphological, physiological, and motor coordination characteristics.

Elite taekwondo athletes showed a lower fat percentage compared to their non-elite counterparts. Previous studies also showed significant differences in anthropometric characteristics between combat sport athletes in judo [5,6], karate [6] and taekwondo [6]. Especially in combat sports with weight categories, fat percentage is one of the most important variables. There are expectations that height will be an important factor or an advantage for elite taekwondo athletes as compared to non-elite taekwondo athletes [7,10]; if one has a longer arm or a longer leg they may be able to reach their opponent or contact point much easier and this can be viewed as an advantage for the athlete. However, based on this study, no significant differences were found between those groups in standing height or body stature. Based on previous studies, it shows that taekwondo is a sport with combination of various parameters of physical characteristics [7,15,19,20].

The physical performance tests revealed better scores in speed (5m sprint) and power (CMJ and squat jump) between elite and no-elite taekwondo athletes. Speed and power have indeed been shown to be relevant determinants of taekwondo performance [19]. Especially lower limb power generation is critical for the execution of powerful kicks [12,13].

While the above results generally corroborate literature findings on the topic, the added value of this study is the observation that medal-winning athletes have better general motor coordination. In contrast to sport-specific motor skill tests (like the execution of a specific kick), the KTK test used in the current study is only affected by sport-specific training to a limited extent, which makes it easier to discriminate innate giftedness from tests scores that are the result of training. This finding might lead to the conclusion that general motor coordination is an important factor in determining who makes it into an elite level in taekwondo and who does not. Indeed, general motor coordination has been proven to be a valuable indicator of an athlete’s potential for progression and as such, an important talent characteristic in skill-based sports such as artistic gymnastics [21] and combat sports [5,6]. For example, elite judo athletes showed better motor coordination and balance as compared to their non-elite colleagues [35]. The underlying assumption is that general motor coordination is a foundation on which sport-specific skills are built, and that an athlete with better coordination will learn new techniques faster and easier [21].

The present study identified that young taekwondo athletes can be differentiated by their fat percentage, sprint 30 m, counter movement jump, squat jump, moving sideways and walking backwards ability. Combination of the variables, especially in physical performance can help coaches and strength conditioning professionals to better understand the performance of their athletes and discover the best approach to improve their training organization. More attention should be given to sprint and explosive power training given the significant differences between elite and non-elite in this study. Nevertheless, this variable can also be used as an early form of detection for young talented athletes in martial arts sports especially in that of taekwondo for the future.

Identifying actual performance is possible with physical performance characteristics such as jumping, running or any physical fitness tests that are already used by researchers in many studies [12,15,20]. Actual performance information is helpful for the coaches and very useful information in developing training program for the athletes. Motor coordination measurements are much more important when identifying the future performance potential, especially to identify and discover the potential in young athletes [6,8,22].

The reconversion from z-scores to actual scores by means of a large database of well-trained individuals has, to our knowledge, not been presented before. It might be an innovative way to draw conclusions on attributes of young potentials, based upon a small sample of elites. Such information is very useful for coaches that are involved in the talent selection and identification process. This approach does however have limitations. Assuming that a given average z-score will hold for young athletes of different ages does not reckon with the observation that talent characteristics are dynamic between 12 and 17 years of age. The relative importance of a given characteristic might change during the talent development phases, and also be affected by biological maturation. Researchers have claimed that biological maturation is an important factor in talent programs, especially for young athletes in sport and it show a significant relationship throughout the development process of athletes [36,37,38]. However, in this study biological maturation did not systematically affect expertise-related differences. A second limitation is that the current reference values in young taekwondo athletes are based upon cross-sectional data. Future longitudinal research should be performed to support our findings. In spite of these limitations, z-scores provide coaches with raw data that are at least indicative for young talented athletes, in the absence of data from large samples of internationally successful athletes. Moreover, the fact that sex and age were not distributed equally for each age group were also another limitation of this study. Apparently, this are the main problem when dealing with the elite population and future researchers should give more attention on this problem to produce a better input in the literature.

CONCLUSION

This study has managed to distinguish between elite and non-elite among taekwondo athletes in terms of their anthropometric measurements, physical performance tests and motor coordination tests. Especially factors like explosivity and general motor coordination seem to be important discriminants between athletes who reach the international top and those that do not. Taekwondo coaches and federations can use this information in their talent identification and development programs, however keeping in mind that anthropometry, physical performance, and coordination are only partial expressions of talent. Such information can be an added value to the expert opinion of the coach because they seem to know and understand their athletes better compared to others. Competition results and psychological factors are valuable to evaluate athlete progression and effectiveness of the training or development program.

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Study 3

Anthropometry, physical performance, and motor coordination of medallist and non-medallist young fencers

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Abstract

Background and Study Aim: Fencing is a sport that relies on a complex intra play of numerous performance characteristics. Evaluation of these characteristics is important in the field of talent identification and talent development. Multidimensional test batteries have proven their value in different sports. The present study aimed to identify anthropometric, physical performance and motor coordination characteristics that discriminate medallist and non-medallist fencers.

Material and Methods: In this cross-sectional study, 83 young fencers (21 national medallists, 62 non-medallist) between 11 and 16 years old were tested in 2010-2015 using a test battery consisting of four anthropometrical, nine physical performance and three motor coordination tests. The fencers were divided into two groups (medallist and non-medallist at national youth championships). First, descriptive analysis explained their general score (means) for anthropometric, physical performance and motor coordination. Second, MANCOVA (multivariate analysis of covariance) was used to explain to what extent the two groups were different from each other, taking into account the effect of maturity (age at peak height velocity – APHV) and calendar age (CA).

Results: Generally, the results showed no differences between medallist and non-medallist fencers in anthropometry, physical performance and motor coordination. APHV significantly affected anthropometry and several strengths, speed and explosivity variables. Chronological age affected nearly all indicators of anthropometry, physical performance, and motor coordination. MANCOVA, correcting for APHV and CA showed no significant difference for anthropometric, physical performances and motor coordination between medallist and non-medallist fencers.

Conclusions: This study a shows a significant effect of APHV and chronological age in anthropometric, physical performance and motor coordination among young fencers. The possibility that only taking into account anthropometry, physical performance, and motor coordination of young fencers in the talent identification process is limited due to the complexity of fencing is discussed.

Keywords: EUROFIT, talent development, talent identification

INTRODUCTION

Talent identification is a serious component of many sports and a scientific approach that has long been of great interest to coaches, researchers, communities and governments. Many countries have implemented formal talent identification (TID) and talent development (TD) models in the sport to increase their success on the international scene. Talent identification (TID) refers to the process of recognising current participants with the potential to excel in a particular sport, while TD provides the required learning environment to maximise this potential (William & Reilly, 2000; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). This process has been implemented in a lot of countries as a model to define talented young athletes in sport to increase their success on the international scene. Suppiah, Low and Chia (2015) reported that the current TID and TD models of sport in youth are not effective and the return of investment are generally subpar, which means that only a few young athletes continue their career to achieve podium positions at the elite sport level in adulthood.

Numerous studies have led to a wealth of data describing the factors that discriminate between athletes of different levels, providing a scientific basis for talent identification programs. Talent identification should play a major role in modern sport, as international competition has become more intense and involved even younger participants (Alabin, Nischt & Jefimov, 1980; Hahn, 1990). Identification programmes help to direct children towards sports (Bloomfield, Ackland & Elliot, 1994) and searching for talent or assessing early development is valuable stages in almost any multi-step sport programme (William & Reilly, 2000; Brown, 2001).

In the past decade, several studies have convincingly demonstrated that the identification of characteristics in young children can form a solid basis to identify those subjects with the chance to excel in the future. Such an approach does not only allow the discrimination between successful and less successful young athletes or the profile of young athletes in specific sports but also allowed to predict the future performance level to a certain extent. Researchers have been investigating different sports for the purpose of talent identification or to distinguish performance and achievement between athletes from different sports and discipline within the same sport and playing the position. This has been demonstrated in skating (Mostaert, Deconinck, Pion & Lenoir, 2016), wrestling (Pallarés, López-Gullón, Torres-Bonete & Izquierdo, 2012), volleyball (Pion et al., 2015a), gymnastics (Vandorpe, 2012; Pion et al., 2015b) soccer (William & Reilly, 2000), judo (Norjali, Torfs, Mostaert, Pion, & Lenoir, 2017) and many other sports (Pion et al., 2015b). Next, to such sport-specific tests, the importance of general motor coordination has long been neglected in the literature (Vandendriessche, 2012; Deprez et al., 2013). The importance of motor coordination has been demonstrated for performance prediction (Pion et al., 2015a) as well as for sports orientation. The same generic test battery showed that it was possible to orient athletes towards different sports (Pion et al., 2015b) as well as to sports that are to a certain extent similar to each other, like martial arts, karate, judo and taekwondo (Pion, Fransen, Lenoir, & Segers, 2014).

Despite the wealth of evidence shortly described above, little information is available on the sport of fencing. Fencing is an Olympic discipline essentially based on the combat of two competitors and winning points are made through the contact with an opponent. The sport is composed of individual and group disputes, using three different combat weapons: a foil, sword or sabre (Cunha & Filho, 2005). Fencing was one of the sports to be played in the Olympics, and this sport has been present since the first modern Olympic Games. The electric sword was introduced in 1936 Olympic Games, the foil in 1956 and the sabre in 1988. Since then the sport has been improved in many ways, i.e. the rules, attire, weapon and the scoring system.

Fencing is an intermittent combat sport with high intensity, relying on the combination of mastery of specific technical skills, tactical decision-making ability, and physical performance. Although success in sports competitions has often been associated with specific anthropometric characteristics for a given sport, the anthropometric data for fencers is limited, inconclusive and mainly reported for descriptive purposes. Analysis of internal proportions of factors of the athletes' body composition revealed significant differences in particular groups of features (Jagiełło, 2017). Anthropometric characteristics seem to be a significant factor to distinguish between differences group or level of participation. The anthropometrical characteristics of fencers show a typical asymmetry of the limbs as a result of the practice of asymmetrical sports activity, and it is difficult to identify a significant relationship between any one physiological characteristic and performance (Roi & Bianchetti, 2008). Previous studies have shown that fencers are taller but more slender with wide shoulders and thinner waists (Ochoa, Gutiérrez, Margain, 2013); Male fencers are taller and have a higher body mass with longer segment lengths compared to female fencers (Ntai et al., 2017). The lower skinfold thickness may be advantageous for faster segmental movements, and lower physiological demands during fencing (Tsolakis & Vagensa, 2010) might also provide fencers with more advantages.

Concerning physical performance, elite fencers are stronger and produced more leg power than national level fencers (Ntai et al., 2017). There was also the previous study discussed on the relation with physiological (Tsolakis & Vagensa, 2010) and dermatoglyphics (finger print) (Cunha & Filgo, 2005). The physiological and morphological profile of world-class fencers were also studied which they measure the dynamic and static strength of the forward and backward extremities individually (Tsolakis & Vagensa, 2010).

Finally, reaction time and spatial anticipation have been suggested to be considered as one of the major predictors of talent in fencing: Elite fencers reduced their time of sensorimotor responses in the middle phase of an attack, i.e. they perceive and make decisions much faster than novice fencers (Borysiuk, & Cynarski, 2010).

Overall, little information is available on profiles of young fencers of different performance levels. A generic, i.e. non-sport specific, test battery (see Material and Methods) has proven its value in discriminating gymnasts, volleyball players, or soccer players of different levels. The study aimed to identify anthropometric, physical performance and motor coordination characteristics that discriminate medallist and non-medallist fencers.

MATERIAL AND METHODS

Participants and design

The data for this study is part of the Flemish Sport Compass (FSC), a project that started in 2007 is still on-going (Vandorpe, 2012; Franse et al., 2012; Matthys et al., 2013). A sample of 83 (43 males and 40 females) fencers between the age of 11 and 16 years were measured in this cross-sectional study during the selection for entering Flemish Top Sport School. Twenty-one were classified as medallist group, managed winning at least one medal in national youth championships competitions one year before or after they were tested, while the remaining 62 were classified as a non-medallist group.

This study has been conducted in accordance with recognised ethical standards (Harris & Atkinson, 2015) and was approved by the local Ethics Committee of the Ghent University

Hospital (Vandorpe et al., 2012). For all participants, written informed parental consent was obtained. None of the participants refused participation.

Measurements

The participants were measured between 2010-2015 and completed four anthropometrical, nine physical performance and three motor coordination tests. A team of experienced examiners from the Department of Movement and Sports Sciences assessed the generic test battery. At any given time, instruction and demonstration were standardised according to the test guidelines (Harris & Atkinson, 2015). The participants performed all tests barefoot except the sprints, the countermovement jump and the endurance shuttle run test, which were all performed with running shoes.

Anthropometry

Height and sitting height (0.1 cm, Harpenden, portable Stadiometer, Holtain, UK), body weight was assessed using a digital balance scale with a foot-to-foot bioelectrical impendence system (0.1 kg, Tanita, BC-420SMA) according to previously described procedures (Vandorpe et al., 2012) and manufacturer guidelines. Arm span was measured with a tape measure in the upright position with arms spread horizontally (to the nearest 0.1 cm). Maturity offset was estimated with Mirwald's gender-specific formula for the age of peak height velocity (APHV) (Sherar, Mirwald, Baxter-Jones, & Thomis, 2005; Malina et al., 2006), which consists of height, sitting height, age and weight.

Physical Performance

Flexibility was assessed by the sit-and-reach test of the EUROFIT test battery with an accuracy of 0.5 cm (Council of Europe, 1988). The shoulder rotation test (Matthys et al., 2013) was used to measure shoulder flexibility (shoulder rotation to the nearest 1 cm). The 10x5m shuttle run (SR) test (EUROFIT) (Council of Europe, 1988) was used to measure speed and agility. The time children needed to run back and forth as quickly as possible between two lines 5 meters apart, 10 times in a row, reflected their speed and agility. To estimate explosive leg power, the countermovement jump (CMJ), hand on the hips and the standing broad jump was performed. The participants performed three single jumps without arm swing recorded with an OptoJump device (MicroGate, Italy).

The highest of three jumps was used for further analysis (0.1 cm) and standing broad jump (SBJ) was measured to the nearest 0.5 cm. Static strength was measured by the handgrip (HG) (Council of Europe, 1988) in Nm. Speed was evaluated by two maximal sprints of 30 meters with split time measured at 10 meters and 20 meters. The recovery time between each sprint was set at two minutes. The fastest time for the 10m sprint, 20m sprint and 30m sprint was used for analysis (Matthys et al., 2011). The sprint tests were recorded with MicroGate Racetime2 chronometry and Polifemo Light photocells at an accuracy of 0.001s (MicroGate, Italy).

Motor Coordination

Gross motor coordination was evaluated using three subtests of the “KörperkoordinationsTest für Kinder” (KTK) (Kiphard & Schilling, 2007). The fourth test hoping for height was not performed, due to the risk of injuries at the ankles (Prätorius & Milani, 2004; Novak et al., 2017). First, participants had to walk backwards along balance beams of decreasing width (6 cm; 4.5 cm and 3 cm respectively). Secondly, participants had to perform two-legged jumps sideways over a wooden slat (2 x 15 s), summing the number of jumps over the two trials. Thirdly, participants had to move sideways on wooden platforms (2 x 20 s), summing the number of relocations over two trials.

Statistical analyses

All data were analysed using SPPS for Windows version 23.0. The present study had a cross-sectional design, involving two study groups: medallist and non-medallist. The basic descriptive indicators (mean and standard deviation) were calculated for all analysed variables. MANOVA was conducted to examine the difference between the medallist and non-medallist fencers for the different anthropometry, physical performance and motor coordination tests. The influence of maturity and chronological age was taken into consideration by the using MANCOVA function. For all analyses, a p-value of <0.05 was used, and partial eta squared was computed to obtain the effect size.

RESULTS

Demographic

APHV was estimated at 14.15 years for medallist group and 14.50 years for the non-medallist group (Table 1).

Table 1. Demographic characteristic of medallist (n = 21) and non-medallist (n = 62) fencers between the age of 11 and 16 years.

Variable (indicator)	**Medallist**			**Non-medallist**		
	overall (n = 21)	**male (n = 9)**	**female (n =12)**	**overall (n = 62)**	**male (n = 34)**	**female (n = 28)**
	The results of empirical variables [M (SD)]					
Calendar age (CA – years)	13.01 (1.29)	13.28 (1.77)	12.83 (0.91)	13.53 (1.77)	13.63 (1.89)	13.38 (1.61)
Age at peak height velocity (APHV – years)	14.15 (0.83)	14.30 (0.55)	14.05 (0.98)	14.50 (1.24)	14.86 (1.03)	13.99 (1.35)

APHV and CA significantly affected anthropometric results. The medallists scored higher in anthropometry compare to the non-medallist fencers, but MANCOVA analysis did not show significant between-group differences (Table 2).

Table 2. Anthropometric indicators of the medallist and non-medallist young fencers.

Variable (indicator)	**Medallist (n = 21)**	**Non-medallist (n = 62)**	**Covariate**		**MANCOVA**
			APHV	**CA**	**F-value (no significant)**
Age at peak height velocity APHV (years)					**1.391**
Chronological age CA (years)					**1.426**
Anthropometric			**	**	**1.221**
Weight (kg)	45.5 (10.15)	45.2 (11.55)	**	**	0.995
Height (cm)	159.43 (12.91)	155.88 (12.11)	**	**	0.833
Sitting height (cm)	82.77 (5.99)	81.68 (6.35)	**	**	0.460
Arm span (cm)	157.00 (12.29)	155.21 (13.37)	**	**	0.297

(**significant difference between groups p<0.01)

Anthropometric

Significant APHV (CMJ, HG, sprint 30m) and CA (SR, CMJ, HG, sprint 5m, sprint 30m) effects on several physical performance tests were observed. There were no significant differences (MANCOVA) in physical performance tests between medallist and non-medallist fencers (Table 3).

Table 3. Physical performance indicators of the medallist and non-medallist young fencers

Variable (indicator)	**Medallist (n = 21)**	**Non-medallist (n = 62)**	**Covariate**		**MANCOVA**
			APHV	**CA**	**F-value (no significant)**
Physical performance			**	**	**0.881**
Sit & reach (cm)	20.38 (7.55)	24.19 (12.69)	n.s	n.s	1.048
Shoulder Flexibility (cm)	90.43 (16.97)	85.97 (21.46)	n.s	n.s	0.284
Shuttle Run (s)	20.59 (1.58)	20.62 (1.56)	n.s	*	0.392
Counter movement jump (cm)	24.77 (6.33)	23.57 (5.29)	**	**	1.160
Standing broad jump (cm)	169.90 (28.58)	166.29 (26.44)	n.s	**	1.461
Hand grip (kg)	24.35 (9.92)	24.10 (10.68)	**	**	0.315
Sprint 5m (s)	1.23 (0.07)	1.27 (0.11)	n.s	**	0.592
Sprint 30m (s)	5.38 (0.50)	5.43 (0.49)	*	**	1.159

(**significant difference between groups $p<0.01$); *trend towards significant $p<0.05$; n.s. no significant; APHV age at peak height velocity; CA chronological age).

Motor coordination

MANCOVA analysis did not result in significant differences in motor coordination tests between the groups (Table 4). Similar to anthropometry and physical performance scores, CA did affect motor coordination performance. The discriminant analysis applied to all tests as predictor variables shows that all the young fencers (80.4%) were correctly classified in their respective group (medallist, non-medallist). Even though the discriminant percentage of

80.4% athletes correctly assigned to the medallist or non-medallist group, it is clear that a significant overlap between the profiles of both groups exists (Figure 1).

Table 4. Motor coordination indicators of the medallist and non-medallist young fencers

Variable (indicator)	**Medallist (n = 21)**	**Non-medallist (n = 62)**	**Covariate**		**MANCOVA**
			APHV	**CA**	**F-value (no significant)**
Motor coordination			**n.s**	******	**0.740**
KTK jumping sideways	86.10 (13.25)	86.13 (11.66)	n.s	**	0.083
KTK moving sideways	55.33 (8.43)	55.47 (10.71)	n.s	**	0.207
KTK walking backwards	47.62 (12.93)	51.95 (13.28)	n.s	**	1.179

(**significant difference between groups p<0.01); *trend towards significant p<0.05; n.s. no significant; APHV age at peak height velocity; CA chronological age).

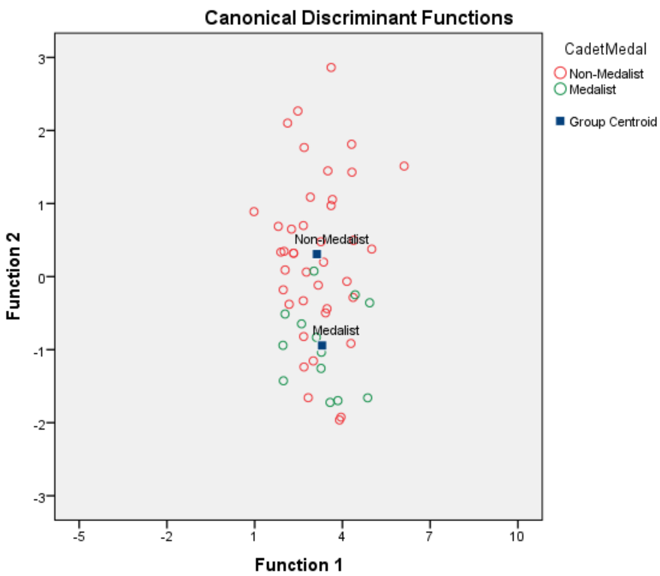

Figure 1. Graphical representation of the discriminant analysis between medallist (n = 21) and non-medallist (n = 62) young fencers.

DISCUSSION

The present study is the first to investigate differences in anthropometric, physical performance and motor coordination between medallist and non-medallist among young fencers using a generic test battery. In general, this study provides the profile characteristics of U16 young fencers, either medallist or non-medallist aged. The main finding of this study is that, apart from the anticipated effects of maturity status and calendar age on anthropometry, physical performance level, and motor coordination, no clear differences between medallists and non-medallists were observed.

The absence of anthropometric differences might be characteristic of the sport of fencing, which allows different profiles to excel at a competitive level. Previous studies also showed no significant differences anthropometric characteristic between athletes of different levels in female water polo (Martinez et al., 2015), powerlifters (Keogh, Hume, Pearson, & Mellow, 2007) and ice hockey players (Agre et al., 1988). Apparently, the nature of the sport dictates to what extent anthropometric variability is allowed and does not hinder performance development, as is the case in youth female artistic gymnastics for example (Vandorpe et al., 2012).

Both the raw data and the results of the MANCOVA resulted in similar profiles of fencers successful and unsuccessful at national youth championships. These results contrast with the similar analysis in other sports like judo, soccer, volleyball or gymnastics (William & Reilly, 2000; Pion et al., 2015a; Norjali et al., 2017) where higher level athletes systematically outperformed their less successful counterparts. Similarly, no significant differences concerning motor coordination were observed in this study, which is also in sharp contrast with the studies mentioned above.

The absence of differences in between the performance levels in this study might be explained from different perspectives. First, the sport of fencing might allow for a large degree of anthropometric, physical performance level, and general coordination in order to excel at national youth competitions. When observing adult elites fencers, remarkable differences in for example anthropometric measurements are present. This might indicate that there is more room for the so-called 'compensation phenomenon' (Alabin et al, 1980) that allows compensating shortcomings on a specific aspect of the athlete's profile by excelling on another component. This might be especially the case in youth fencers. Such a phenomenon is hardly present in sports like female artistic gymnastics, where profiles of the majority of the athletes are rather homogeneous. A second explanation might stem from the idea of 'proficiency barrier' that is well known in motor development research (Seefeldt, 1980).

The group observed in this study might be so far above average in most of the characteristics observed concerning reference values for that age group, that they all achieved the minimum requirements of the variables measured here that are necessary to excel. As a result, the variables in this study have no discriminant value anymore in this selected group. Related to this argument, the sport of fencing is featured by its open and unpredictable character, also relying on decision-making capacities that were not measured in this study. So future research on young fencers should include one or several measures of perceptual-cognitive evaluations like response inhibition, reaction time, that subserve the decision-making process. Finally, the absence of differences between groups at a specific point in time does not allow conclusions on the potential predictive power of this generic test battery in the future, as has been shown already in judo and gymnastics. Research with a longitudinal character might shed more light on this issue in the future.

CONCLUSIONS

Apart from the anticipated effects of maturity and calendar age on anthropometry, physical performance, and general coordination, no differences between successful and less successful athletes were observed. This contrasts with earlier studies in other sports using a similar test battery and pleads for the inclusion of other variables with discriminative power in fencing, which is likely to be situated at the level of decision-making ability. In addition, a longitudinal follow-up study could shed light on the long-term predictive power of a generic test battery for talent identification.

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STUDY 4

Profiles of physical fitness and enjoyment among children: Associations with sports participation

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In preparation

Abstract

Background and Study Aim: Motivational factors (e.g., enjoyment) are positively associated with physical activity participation in children and adolescents. Understanding the interrelationship between enjoyment and factors such as physical fitness will help to further improve existing and develop and implement new physical activity and sports programs. The present study aimed to examine 1. whether groups of children with different profiles in terms of physical fitness and enjoyment in fitness-related activities could be identified, and 2. whether groups with different profiles varied from one another in terms of organized sports participation.

Material and Methods: A sample of 558 Belgian children (318 boys; 56.99%) aged 8-11 years participated in this study with a retrospective cross-sectional design. Participants' physical fitness was assessed with seven items from a standardized test batterywhile their enjoyment was measured by means of a pictorial scale containing seven pictures referring to the enjoyment in the seven physical performances tests. To examine whether groups with different profiles in relation to physical fitness and enjoyment could be identified, we conducted cluster analyses based on standardized scores of children's performance on and enjoyment in the seven fitness tests. To investigate differences in weekly-organized sports participation among each of the identified groups, an ANOVA was conducted.

Results: Cluster analyses revealed two groups with aligned levels of physical fitness and enjoyment (i.e., relatively low – low and relatively high – high) and two groups with

unaligned levels of physical fitness and enjoyment (i.e., relatively low – moderate and relatively high – moderate). Significant differences in weekly organized sports participation were found among the groups with the two groups of children with relatively high fitness scores spending significantly more time in organized sports (*M*=2.01hrs and 2.29hrs, respectively) than the two groups with relatively low fitness scores (*M*=1.08hrs and 0.98hrs, respectively), irrespective of their enjoyment levels.

Conclusion: This study shows that children with (relatively) high fitness levels spend more time in organized sports than their peers with lower fitness levels, regardless of their level of enjoyment in physical fitness activities. As such, children's fitness levels may be more decisive in terms of sports participation than their enjoyment levels.

Introduction

Approximately 20-25% of children in Europe are overweight or obese (Brug et al., 2012). Furthermore, overweight or obese children are more likely to become overweight adults (Singh, Mulder, Twisk, Van Mechelen, & Chinapaw, 2008). Given its negative health consequences (Holfelder & Schoot, 2014), these high levels of overweight or obese children remain a major public health concern (Lobstein, Baur, & Uauy, 2004; Reilly, Houston-Callaghan, Donaghey, & Hammed, 2010) and significant efforts have been made to develop approaches to prevent childhood obesity (Lifshitz, 2008; World Health Organization, 2012). One of these efforts relates to the promotion of physical activity participation among children. Previous studies have mainly focused on elementary school students or young children (Hebert, Møller, Andersen, & Wedderkopp, 2015; Holfelder & Schoot, 2014;

Lubans, Morgan, Cliff, Barnett & Okely, 2010) and discussed the importance to practice a healthy lifestyle. Regular physical activity has physical, mental and social health benefits, including a reduced risk of overweight and obesity (Janssen & Leblanc, 2010; World Health Organization, 2012). A structured form of physical activity is sport, which is popular among children and linked to different positive health outcomes (Eime, Young, Harvey, Charity, & Payne, 2013). As such, understanding the factors that influence sport participation is crucial in order to encourage children to engage in physical activity and develop an active lifestyle.

In their conceptual framework, Stodden et al. (2008) describe the dynamic relationship between physical activity and other health-related factors, and how these factors interact (Robinson, Stodden, Barnett et al., 2015). One of these factors is physical fitness, which refers to the capacity to carry out physical activity (Ortega, Ruiz, Castillo, & Sjöström, 2008). Physical fitness is a multi-faceted concept and involves health-related components such as cardiorespiratory endurance, muscular strength and endurance, speed and agility, and flexibility (Caspersen, Powell, & Christenson, 1985). Stodden and colleagues' (2008) model describes how children with higher levels of physical fitness will be more likely to participate in and maintain physical activity and develop motor skills, which will reduce the risk of unhealthy weight gain. This will in turn positively influence their levels of physical fitness, motor competence and physical activity, leading to a positive spiral of engagement in physical activity. As such, physical fitness can be seen as an important determinant of youngsters' sport participation (Perkins, Jacobs, Barber & Eccles, 2004). Yet, some youngsters' may be physically fit, but still not continue their sport participation in the long run, particularly when their sport experiences are not inherently satisfying.

It is therefore important to consider youngsters' experienced enjoyment in relation to their sport participation. Enjoyment can be defined as a positive state of affect reflecting feelings of pleasure, fun and excitement (Wankel, 1993). Previous literature has shown that enjoyment is positively associated with physical activity participation (Motl et al., 2001; Bailey, Cope & Pearce, 2013) in children and adolescents. Moreover, enjoyment is considered among the strongest predictors of physical activity (Cairney et al., 2012). According to Deci and Ryan's Self-Determination Theory (Ryan & Deci, 2000), when individiuals engage in physical activity because they experience enjoyment and satisfaction directly from participation, they are intrinsically motivated, with the latter reflecting the most self-determined regulation of behaviour. Intrinsic motivation has been shown to be positively associated with physical activity (De Meester et al., 2016a) Enjoyment can thus be seen as an important factor in motivation for and participation in physical activity. As noted by Barnett, Ridker, Okechukwu, and Gortmaker (2017), enjoyment should be considered in health interventions as it is positively related to physical activity. However, while previous research has shown that enjoyment is linked to physical activity (Barnett et al., 2017), little is known on how enjoyment is related to other factors influencing physical activity such as physical fitness (but see Gao (2008) and Eberline et al. (2018) for an exception). Furthermore, most previous studies exploring the role of enjoyment in a sports (McCarthy, Jones, & Clark-Carter, 2008) or more general physical activity (Carroll & Loumidis, 2001) context used a variable-centered approach which only provides information on the strength of the associations between variables (Magnusson, 1988). To our knowledge, no previous studies applied a person-centered approach, which enables the identification of groups of children who share certain attributes or relations among attributes (in this case physical fitness and enjoyment; Magnusson, 1988). Such an approach is considered to be a prominent way to analyze data that relate to the notion of physical literacy (Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019) as it can provide insight into the association between physical fitness and enjoyment at the individual level, as well as their collective association with sports participation. As such, the present study will rely on a person-centered approach to (1) explore whether different fitness-enjoyment based profiles (e.g., high fitness-low enjoyment/ low fitness-high enjoyment) exist among elementary school; and (2) investigate whether there are differences in organized sports participation between children with different profiles. Based on previous studies that have explored the association between (actual and perceived) motor competence and motivation among children and adolescents (Bardid et al., 2016; De Meester et al., 2016a), we hypothesized that different profiles could be identified with children having corresponding levels of fitness and enjoyment (i.e., relatively high-high or low-low) or contrasting levels (i.e., relatively high-low or low-high). In line with prior research (De Meester et al., 2016b), we also hypothesized that children with a profile with relatively high levels of physical fitness and/or enjoyment would demonstrate higher levels of sports participation than children with a profile with relatively low levels of physical fitness and/or enjoyment.

Methods

Participants and procedure

Principals from 21 schools from a school district in Ghent, Belgium were contacted to participate in this study. However, only fifteen pricipals gave approval for participation of their school in this study. Their parents received an information letter and all parents consented to the participation of their child. A sample of 558 Belgian children (318 boys;

56.99%) aged 8-11 years participated in this study. The current study was conducted in accordance with recognized ethical standards (Harriss & Atkinson, 2015), and was approved by the Ethics Committee of the Ghent University Hospital.

Measures

Physical fitness

Participants' physical fitness was assessed with seven tests (see below for a description of each test) from a standardized test battery (Vandorpe et al., 2012). Validity and reliability of each of the tests have been shown to be very high (Vandorpe et al., 2012). At any given time, instruction and demonstration were standardized according to the test guidelines. The children performed all tests barefooted (to ensure uniformity of test conditions) with the exception of the sprints, the counter movement jump and the endurance shuttle run test, which were all performed with running shoes for safety reasons.

Flexibility of the trunk and upper legs was assessed by the sit-and-reach (best of two attempts) test of the Eurofit test battery (Council of Europe Committee for the Development of Sport, 1988) with an accuracy of 0.5 cm. Abdominal strength was determined through the performance of sit-ups (one attempt) according to the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition manual (BOT-2; Bruininks & Bruininks, 2005), requiring the athletes to execute as many push-ups as possible in 30 seconds. Functional arm strength was measured by knee push-ups (one attempt) according to the BOT-2 procedures and requiring them to do as many push-ups as possible in 30 seconds. Static strength (HGR-DO) was measured in kg by means of a maximal handgrip test (best of two attempts) (Council of Europe Committee for the Development of Sport, 1988). To estimate explosive strength

(SBJ-DO), the standing broad jump as described in the Eurofit test battery was performed (Council of Europe Committee for the Development of Sport, 1988) and the best score of two jumps was used for further analysis (0.1 cm). Agility and speed was determined with the 10x5m shuttle run (one attempt) according to Eurofit test. Cardiovascular endurance was obtained using the 20-m endurance shuttle run test (ESR, 0.5 min; Council of Europe Committee for the Development of Sport, 1988). Children had to run back and forth between two lines 20 meters apart, at a speed that was imposed by means of beep signals. As the test progressed, the time provided to reach the other side gradually decreased, requiring the children to run faster and faster. Failure to cross the other line before or on the beep was only allowed once.

Enjoyment

The participants' enjoyment was measured by means of a pictorial scale containing seven pictures referring to the physical performances tests described above. Children were presented with a series of pictures of children demonstrating physical performance characteristics like explosive strength of the lower legs, or endurance running. Pictures were displayed on a tablet computer and were scored on a scale from 0 to 10 depending on how much the participants liked to do the task presented (0 = not at all; 10 very much). The reliability was measured with a test-retest of 34 participants. The obtained intraclass correlations (ICC) were moderate to high according to the criteria of Steiner and Norman (2003): flexibility (ICC = 0.436); abdominal strength (ICC = 0,588); functional strength (ICC = 0,456); static strength (ICC = 0,679); explosive strength (ICC = 0,692); speed and agility (ICC = 0,656); cardiovascular endurance (ICC = 0,789).

Sports participation

Children's weekly participation in organized sports was assessed with an adapted form of the Flemish Physical Activity Questionnaire, a reliable and valid instrument to measure different dimensions of physical activity in children (Verstraete, Cardon, Trost, & De Bourdeaudhuij, 2006; Philippaerts et al., 2006). Children were first asked whether or not they participated in organized sports. Children who did participate in organized sports were then asked how much time (per week) they usually engaged in organized sports.

Analyses

First, we calculated the descriptives for all the variables and examined the correlations among each of the variables. To examine whether groups with different profiles in relation to physical fitness and enjoyment could be identified, we conducted cluster analyses based on standardized scores of children's performance on and enjoyment of seven fitness skills. In a preliminary step, percentile scores were computed for each of the seven physical fitness tests (and inverted for the 10x5m shuttle run as a lower time indicates a better performance on this test) and each of the seven enjoyment measurements. The obtained percentile scores were then used to compute a composite score for general physical fitness and for general enjoyment, respectively. After standardizing both composite scores, we checked for univariate (values of more than three standard deviations above or below the mean) and multivariate outliers as identified using the Mahalanobis distance measure (Mahalanobis, 1936) as they can significantly perturb cluster solutions (Gore, 2000). Univariate outliers were not found. However, we identified and subsequently removed seven multivariate outliers, resulting in a final sample of 549 children.

A cluster analysis was then conducted by means of a two-step procedure (Gore, 2000). In the first step, Ward's hierarchical clustering method (Everitt, Landau, & Leese, 2001) was used to conduct a hierarchical cluster analysis. Clusters that were alike in terms of squared Euclidean distance were combined, resulting in three-, four-, and five-cluster solutions. In the four- and five-cluster solutions, the explained variance in both physical fitness and enjoyment was at least 50% (Milligan & Cooper, 1985). However, in the three-cluster solution the explained variance in enjoyment was only 47.3%. As such, only the four- and five-cluster solutions were retained for further analyses. In the second step, the cluster centres were used as non-random initial cluster centres in an iterative, non-hierarchical k-means clustering procedure (Asendorpf, Borkenau, Ostendorf, & Van Aken, 2001) and the resulting cluster solutions were evaluated based on interpretability and parsimony (Eye & Bogat, 2006).

Subsequently, we conducted a double-split cross-validation procedure to check the stability of both cluster solutions (Breckenridge, 2000). After randomly splitting the total sample into two equal subsamples and repeating the entire two-step procedure (Ward and k-means) in both subsamples, the participants in each subsample were assigned to new clusters based on their Euclidean distances to the cluster centres of the other subsample. These newly formed clusters were then compared for agreement with the original clusters by computing Cohen's kappa (K). The two resulting kappa's for each of the cluster solutions were averaged, resulting in a kappa of .93 for the four-cluster solution (i.e., very good stability and replicability; Mahalanobis, 1936) and .71 for the five-cluster solution (i.e., good stability and replicability; Mahalanobis, 1936) respectively. Since the four-cluster solution scored better on stability and replicability than the five-cluster solution and explained 66.0% and 71.2% of the variance in physical fitness and enjoyment, respectively, the four-cluster solution (Figure 1) was considered the best fit for further interpretation. To define each of the four clusters, standardized mean scores of both physical fitness and enjoyment were inspected. Furthermore, we conducted a one-way MANOVA to examine whether the clusters, as intended, differed from each other in terms of physical performance and enjoyment.

To investigate differences in weekly-organized sports participation among each of the clusters, a one-way ANOVA was conducted. Sheffe post hoc analyses were then applied to identify significant differences between clusters. All statistical analyses were conducted in IBM SPSS Statistics 22.0. Statistical significance was set at $p < .05$.

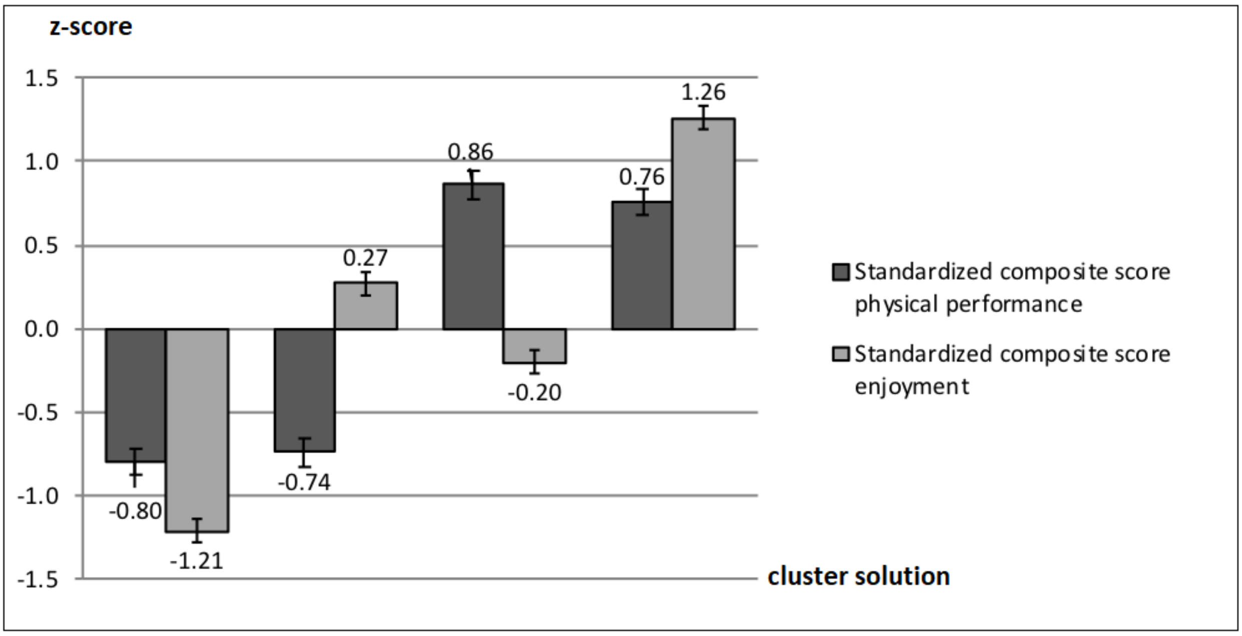

Figure1. Four cluster solution based on z-scores for physical fitness and enjoyment.

Results

Descriptives

Table 1 provides an overview of the means and standard deviations of the participants' physical fitness, enjoyment, and weekly-organized sports participation, along with the correlation coefficients among each of the study variables**.**

Table 1. Descriptive statistics and correlations among physical fitness, enjoyment and organized sports participation.

Variables	***M***	***SD***	***Min***	***Max***	***1***	***2***
1 Physical fitness (percentile)	50.03	17.86	9.46	90.72		
2 Enjoyment (percentile)	50.34	17.08	8.72	87.31	.35***	
3 Weekly organized sports participation (hours/week)	1.56	1.90	0.00	13.00	.37***	.19***

Note. N=549 (318 boys); ****p* < .001.

Table 2 shows the means and standard deviations of the actual physical fitness scores and the enjoyment scores, as well as the Pearson correlations among each of the seven physical fitness test scores and the corresponding enyoyment scores.

Table 2. Descriptive statistics and correlations among the physical fitness test scores and the enjoyment scores

Variables	**Physical fitness (actual score)**		**Enjoyment (Scale 1-10)**		**Pearson Correlation**
	Mean	**SD**	**Mean**	**SD**	
Flexibility	17.5 cm	6.7	5.5	2.7	0.223**
Sit-Up	24.7 rep	7.5	6.3	2.8	0.231**
Knee Push-up	21.9 rep	7.5	6.9	2.5	0.256**
Hand Grip	18.0 kg	4.6	7.7	2.5	0.128**
Standing Broad Jump	136.8 cm	19.9	7.2	2.3	0.134**
Shuttle Run	24.6 s	2.2	7.8	2.2	-0.171**
Endurance Shuttle Run	4.8 min	2.2	7.4	2.7	0.420**

**indicates a significant difference between groups (p<0.01). SD= Standard deviation

Identifying clusters

As shown in Figure 1, four approximately equal clusters were identified. The clusters were labelled based on their relative scores (i.e., in comparison to the study sample) for physical fitness (low, moderate, high) and enjoyment (low, moderate, high), respectively. The first cluster (n=133; 24.2%) was characterized by children who, in comparison to children belonging to the other clusters, scored low on physical fitness and low on enjoyment. This cluster was labelled the 'low-low' cluster. The second cluster (n=151; 27.5%) comprised children who had, relative to children belonging to the other clusters, low scores on physical fitness but moderate scores on enjoyment and was consequently labelled the 'low-moderate' cluster. Children in the third cluster (n=142; 25.9%) had, relative to children belonging to the other clusters, high scores on physical fitness but moderate scores on enjoyment. This cluster was labelled the ‘high-moderate’ cluster. The fourth and final cluster (n=123; 22.4%) was characterized by children who had, relative to children belonging to the other clusters, high levels of both physical fitness and enjoyment and was labelled the ‘high-high’ cluster. Chi-square analyses, $\chi2(3)=51.80$, $p<.001$, revealed an overrepresentation of girls (38.3% boys vs. 61.7% girls) in the ‘low-low’ cluster, while boys were overrepresented (82.1% boys vs. 17.9% girls) in the ‘high-high’ cluster. A more proportionate sex representation was found within the ‘low-moderate’ (53.6% boys vs. 56.4% girls) and the ‘high-moderate’ cluster (59.9% boys vs. 40.1% girls).

As intended by performing cluster analyses, there was a statistically significant difference in physical performance and enjoyment based on a cluster classification, $F(6, 1088) = 412.68$, $p < .001$; Wilk's $\Lambda = 0.09$, partial $\eta2 = .70$. Sheffe post hoc analyses revealed that the ‘low-low’ (M=35.65; SD=12.26) and the ‘low-moderate’ (M=36.67; SD=9.58) clusters had significantly lower average percentile scores for physical fitness than both the ‘high-moderate’ (M=65.71; SD=10.02) and the ‘high-high’ cluster (M=63.88; SD=10.76; $F[3, 545]=331.43$, $p<0.001$, $\eta2=0.65$). All four clusters differed from each other in terms of enjoyment ($F[3, 545]=599.09$, $p<0.001$, $\eta2=0.77$). More specifically, the ‘high-high’ cluster had the highest mean percentile score (M=72.03; SD=7.23), followed by the ‘low-moderate’ cluster (M=54.81; SD=46.65), the ‘high-moderate’ cluster (M=46.65; SD=9.45) and the ‘low-low’ cluster (M=29.14; SD=7.57), respectively (see Table 3).

Table 3. Mean scores and cluster comparisons for the four clusters (*N*=549).

	Cluster			
	Cluster 1: Low-low	**Cluster 2: Low-moderate**	**Cluster 3: High-moderate**	**Cluster 4: High-high**
	n=133	*n=151*	*n=142*	*n=123*
	51 boys	81 boys	85 boys	101 boys
	82 girls	70 girls	57 girls	22 girls
	24.2%	27.5%	25.9%	22.4%
Variable				
Cluster dimensions (z-scores)				
Physical fitness	-0.80 (0.68)[a]	-0.74 (0.53)[a]	0.86 (0.55)[b]	0.76 (0.60)[b]
Enjoyment	-1.21 (0.44)[a]	0.27 (0.49)[b]	-0.20 (0.54)[c]	1.26 (0.42)[d]
Cluster dimensions (percentile scores)				
Physical fitness	35.65 (12.26)[a]	36.67 (9.58)[a]	65.71 (10.02)[b]	63.88 (10.76)[b]
Enjoyment	29.14 (7.57)[a]	54.81 (8.44)[b]	46.65 (9.45)[c]	72.03 (7.23)[d]
Child outcomes				
Weekly organized sports participation (hrs/week)	1.08 (1.34)[a]	0.98 (1.36)[a]	2.01 (2.07)[b]	2.29 (2.38)[b]

Note. Values in parentheses are standard errors. A cluster mean is significantly different from another mean if they have different superscripts. Differences between the four clusters were tested by means of post hoc analyses.

Differences between clusters in terms of weekly-organized sports participation

The one-way ANOVA indicated significant differences in average weekly time spent in organized sports participation among clusters, $F(3, 545)=17.65$, $p<0.001$, $\eta^2=0.09$. Children in the 'low-low' cluster (M=1.08 hours per week; SD=1.34) and the 'low-moderate' cluster (M=0.98; SD=1.36) participate significantly less in organized sports than children in the ‘high-moderate’ (*M*=2.01; *SD*=2.07) and the ‘high-high’ cluster (*M*=2.29; *SD*=2.38; see Table 2).

Discussion

The main objectives of this study were to explore how children with different fitness-enjoyment based profiles differed in weekly organized sports participation using a person-centred approach. Our study identified four, approximately equal-sized, profiles with different patterns between physical fitness and enjoyment. In line with our hypothesis, we identified two groups of children with corresponding levels of fitness and enjoyment (i.e., one group with relatively high scores on both and one group with relatively low scores on both). Furthermore, we also identified a group of children with relatively low scores in physical fitness but relatively moderate scores in enjoyment, and a group of children with relatively high physical fitness scores but relatively moderate enjoyment scores. These results indicate that enjoyment levels in fitness-related exercises and actual physical fitness levels, although overall positively related, are not directly proportional in all children. These findings shine a new light on the results of previous studies that revealed positive correlations between children’s and young adolescents’ enjoyment (measured by the degree to which participants liked exercising and enjoyed physical exertion in Eberline et al., 2018; and measured with a subscale of the Intrinsic Motivational Inventory in Gao, 2008) and their cardiorespiratory fitness (measured with the PACER in both studies).

Our results also show significant differences among the groups with different fitness-enjoyment based profiles in terms of weekly time spent in organized sports. In line with our hypothesis, children with relatively high levels of both physical fitness and enjoyment were found to spend significantly more time in organized sports than their peers with relatively low levels of both. According to Self-Determination Theory (Ryan & Deci, 2000), children who participate in sports simply because they enjoy doing so, are autonomously motivated (i.e., the most optimal form of motivation) and will participate more in sports than theirs peers who participate because they feel pressured (from within or above) to do so. Furtermore, we found that within the group of children with relatively moderate levels of enjoyment, those with higher physical fitness levels participated more in organized sports than those with lower physical fitness levels. This shows that, among children who moderately enjoy fitness-related exercises, actual physical fitness may be a decisive factor for (the degree of) participation in organized sports. These findings provide further evidence for the reciprocal and positive relationship between physical fitness and organized sports participation in youngsters in general (Agata & Monyeki, 2018; Phillips & Young, 2009; Zahner et al., 2009).

Practical implications and recommendations for future research

Based on the current study, it is highly recommended that health practitioners focus on increasing children's physical fitness levels. Special attention should be paid to children with low or moderate levels of enjoyment as the results indicate that improved physical fitness may lead to increased sports participation within this group with sub-optimal enjoyment levels. This positive relationship could then (further) reinforce the so called positive spiral of engagement (Stodden et al., 2008; Robinson, Stodden, Barnett et al., 2015) resulting in higher levels of (actual and perceived) motor competence, physical fitness, and general physical activity engagement, and a healthier body weight.

The combination of physical performances and enjoyment seems to be an important factor in the involvement of children in organized sport. Previous studies have shown decreasing participation rates in sport with increasing age (Brettschneider & Naul, 2007) and several researchers have also mentioned that the proportion of 15- to 19- year-old adolescents regularly participating in sports dropped (Berger, O'Reilly, Parent, Se Séguin, & Hernandez, 2008) in several sports (Eime, Harvey, Charity, & Payne, 2016). As such, future research should investigate potential factors associated with enjoyment and might refer to the recent study (Barnett et al, 2017) that already considers the challenge regarding physical activity enjoyment for children, in an effort to inform teaching and coaching practices, and to increase physical activity engagement.

Strengths and limitations

A major strength of this study is the use of a person-centered approach, which allows us to identify profiles of physical fitness and enjoyment among children and to investigate how these profiles differ with respect to sports participation. Additionally, this study has a large sample size, which improves cluster reliability when conducting cluster analyses (Breckenridge, 2000) and allows generalization of the study results. A limitation of this study is its cross-sectional design, which prevents us from determining any causality between physical fitness, enjoyment, and sports participation. Future studies should involve a longitudinal design to gain more insight into the direction of these relationships. Another limitation is the sole focus on organized sports participation. Associations between enjoyment and unstructured forms of physical activity should be explored as well in future investigations, as these tend to be more self-directed (Ennis, 2017). Finally, while the current study provided insight on enjoyment regarding specific fitness tests, future research should explore sources of enjoyment in sports participation to further refine the design of engaging youth sports programs.

Conclusion

This study provided us with general information on the levels of physical fitness and enjoyment among children in Flanders. Four different groups with respect to the level of physical fitness and enjoyment were identified, with the two groups with a better score on physical fitness displaying the highest weekly time spent in organized sport. Increasing physical fitness levels (especially among those children with suboptimal enjoyment levels) may lead to increased organized sport participation. As such, it is recommended that future interventions try to improve the enjoyment level and fitness level using a multiple approach such as increase the numbers of awareness program or health promotion programme especially among youngsters. This enjoyment will increase the intrinsic motivation factor, which is beneficial for sustained sports participation as well as to maintain a healthy lifestyle. In addition, more research about enjoyment should be conducted and the relationship between the transitions from primary school to secondary school might also be an interesting factor to look at.

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PART 3: GENERAL DISCUSSION

1. Summary of the main findings (Figure 1)

The general aim of this dissertation was to expand our understanding on the importance of anthropometric, physical performance and motor coordination attributes in talent identification and athlete performance, especially in combat sports. In first three studies, we investigated the relationship between performance on a test battery that mainly consisted of non-sport specific tests, and the ultimate outcome of the talent identification and development program, namely the level of competitive success. The studies were conducted on samples of young athletes between 11 and 17 years old in judo, taekwondo, and fencing (epee) that have been categorised in different groups based on their competitive achievements. In this dissertation, we also touched upon the motivational basis of sport participation, the latter being a necessary "precursor" of talent identification. The objective of the final study was to examine the relationship between the combination of performance and enjoyment levels and participation in organized sports among children (8-11 years).

In the first study regarding male judo athletes (U14), our aim was to distinguish between drop-out, sub-elite and elite judo athletes with respect to their anthropometric, physical performance and motor coordination tests. The elite group performed better in most of the tests which is what was expected. Moreover, discriminant analysis demonstrated that there were significant differences between drop-out, sub-elite and elite judo athletes with respect to anthropometric measurements. However, no significant differences were found between the groups in physical fitness and motor coordination tests.

In the second study in young taekwondo athletes, we tested athletes aged between 12 years to 17 years old and grouped them as elites and non-elites. Overall, elite taekwondo athletes scored better compared to the non-elite group in anthropometric, physical fitness and motor coordination tests. More specifically, elites outperformed their lower level peers in lower fat percentage, sprint speed, explosivity, and general body coordination.

The third study was conducted to identify anthropometric, physical performance and motor coordination characteristics that discriminate medallist and non-medallist fencers. This study involved young fencers (11 years to 16 years) and divided them according to performance level. In contrast to the previous outcomes of in this dissertation, no differences between medallist and non-medallist young fencers on anthropometric, physical performance and motor coordination emerged.

For the fourth study, we measured the actual performances and the level of enjoyment in children between 8 years to 11 years old. This final study aimed at identifying different profiles or combinations of children's physical performance and enjoyment (motivational) in organized sports participation. In this study, 4 profiles were defined based on the physical fitness score and level of enjoyment (low-low, low-moderate, high-moderate, high-high). This study showed that the degree of sport participation was related to the nature of the combination of performance and enjoyment at the child's level. The results and connection of the four studies have been summarized in Figure 1 below.

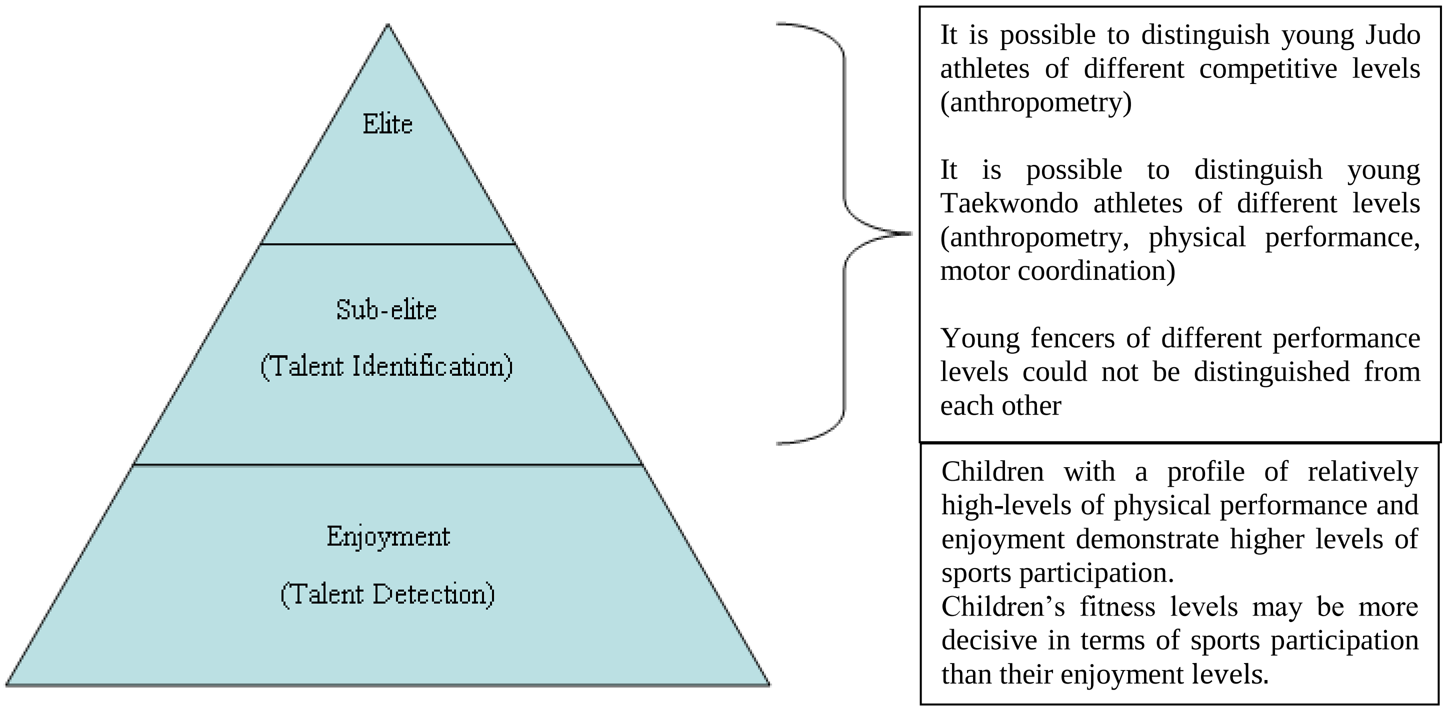

Figure 1: Summary of the research findings

2.Contribution to the area of TID

2.1 Anthropometry

In many all combat sports such as judo and taekwondo, athletes are categorized into a series of weight classes that are intended to promote fair competition by matching opponents of equal stature and body mass (commonly referred to as ''weight'' within the sport) (Langan-Evans, Close & Morton, 2011). However, this is not the case in fencing as the athletes are categorised according to the weapon categories. Anthropometric measurements have been an important component not just for talent identification but also to distinguish performance parameters between athletes from different sport, and disciplines within the same sport and playing position (Ntai, Zahou, Paradisis, Smirniotou & Tsolakis, 2017).

Based on the descriptive data of this study, the young fencers generally scored higher on anthropometric dimensions than the young judo athletes. In addition, the young taekwondo athletes showed more favourable anthropometric characteristics when compared to young judo and fencing athletes. This finding is in line with the previous study (Pion, Fransen, Lenoir & Segers, 2014) which demonstrated that young taekwondo athletes generally had higher scores on anthropometry when compared to other young combat sports athletes. Results of the anthropometric measurements (BMI and Fat percentage) for young judo and young taekwondo athletes were also supported by previous studies in junior athletes (Pacecco, Faulhaber, Franchini & Burtscher, 2012; Bridge, da Silva Santos, Chaabene, Pieter, & Franchini, 2014).

Moreover, anthropometric measurements were able to distinguish young combat sports athletes (Judo, Taekwondo) in different levels, but not in young Fencing athletes. Elite/medallist young athletes in the three sports performed better in anthropometric measurements compared to other groups. This finding showed that anthropometric measurement (e.g weight) is one of the important characteristics in weight classes sports (Judo, Taekwondo) but not in the weapon classes sport such as fencing.

Several studies have pointed out the importance of some anthropometrical parameters to improve judo performance (Franchini, Takito, Kiss, & Strerkowicz, 2005; Yamamoto, 2006). Franchini et al., (2011) reported that world-class male judokas have a body fat percentage lower than 10% and it tends to decrease in those competitors who are better ranked. Previous studies also showed significant differences in anthropometric characteristics between combat sport athletes in judo (Norjali Wazir et al., 2017; Pion et al., 2014), karate (Pion et al., 2014) and taekwondo (Poliszczuk et al., 2016; Pion et al., 2014), in young as well as in adult combat athletes. Taekwondo athletes with high performance levels are taller and have a lower amount of fat percentage than athletes with lower performance levels. (Marković, Misigoj-Durakovic & Trninic, 2005).

Although a similar classification method was used in the study on young elite fencers, no significant differences were observed in any of the anthropometric, physical fitness and motor coordination tests obtained in medallist and non-medallist athletes. In terms of the anthropometric aspects of the sport, this finding is in line with literature available on adult fencers. Tsolakis and Vagenas (2010), showed that anthropometry, as a whole, did not lead to a significant differentiation between elite and sub-elite groups of fencers. Although no significant differences were found in the anthropometry characteristics among the fencers, still, one should not omit the anthropometric parameters from a test battery but rather search for other anthropometric measurements (e.g. arm span, skinfold) to assist in the search for more talented fencers. Anthropometry components seem to be a beneficial factor in distinguishing between young combat sport athletes and between different groups, especially in Judo and Taekwondo.

2.2 Physical Performance

From the current knowledge (Pion et al, 2014; Tabben et al, 2014), we expected significant differences between the three combat sports in different groups on physical performance tests. Most combat sports require a high level of technique, tactical excellence and physical fitness, especially strength, aerobic fitness, muscle power and speed (Chaabene et al., 2012). The descriptive data of this study showed that young taekwondo athletes performed better in physical performance tests when compared to judo and fencing young athletes. Young taekwondo athletes were faster in the sprint test followed by judo and young fencing athletes. This is in contrast with the study of Tabben et al., 2014), who reported no significant differences in sprints between Judo and Taekwondo athletes. The finding could be explained by the fact that speed is necessary for effective use of the techniques in martial arts and reacts with maximal speed to the opponents' actions. In turn, young judo athletes generally appeared to be better in the physical performance tests compared to young fencing athletes.

Nevertheless, young taekwondo athletes also performed better in the Sit and Reach, and Counter Movement Jump (CMJ) tests compared to young judo and fencing athletes. These findings are in line with the study by Schwartz et al., (2015), which mentioned that taekwondo athletes performed better in flexibility than judo athletes. The better score in the CMJ test can be explained with a previous study that reported taekwondo athletes use kicks more frequently during a match (Bridge, Jones, & Drust, 2011; Casolino et al., 2012).

Looking at the individual sports studied in this dissertation, most of the findings are in line with sport-specific literature in adult athletes. In the judo study, the young elite athletes tend to show better results in the 5m sprint test, 30m sprint test, sit-and-reach test, sit ups and beep test. Even though the elites scored better in the physical performance tests, the physical performance tests could not distinguish young judo athletes in different groups. There were no statistical differences in physical performances in judo athletes in different groups, which is similar to previous studies (Drid et al., 2015; Franchini et al., 2005).

For the taekwondo study, the young elite athletes performed better in the majority of the physical performance tests when compared to their counterparts. The combination of excellent speed and power enabled a process of discrimination between taekwondo athletes of different competition levels. Previous research showed that international female medallists performed higher in CMJ compared with non-medallists (Marković et al., 2005) and senior athletes performed better compared to their junior counterparts (Chiodo et al., 2011; Chiodo et al, 2012). The speed component is also an important factor for taekwondo athletes and previous researchers have mentioned that successful male (Sadowski, Gierczuk, Miller, & Cieslinski, 2012) and female (Marković et al., 2005) competitors perform faster than their less successful counterparts.

Meanwhile, in the fencing study, there were no significant differences between medallist and non-medallist the physical performance tests. It is difficult to identify a significant relationship between any of the physiological characteristics and performance levels of fencers (Roi & Bianchedi, 2008). Similar findings were also found by the study of Nyström et al., (1990), who had mentioned that there were no significant differences found in isometric leg strength in the forward and backward legs among fencers. Other physical fitness components might distinguish between the two groups, such as the reaction time (Borysiuk, & Cynarski, 2010). Related to this argument, the sport of fencing is featured by its open and unpredictable character, also relying on decision making capacities (Feng, Zhou, Zhang, & Tian, 2010) that were not taken into account in this study. As a result, fencing can be considered as one of the sports in which there is not one single set of characteristics that is uniquely related to performance. This is also the case in other sports that rely on a large variety of characteristics like soccer, handball, hockey and basketball (Vaeyens et al., 2008).

Although no significant differences were found in physical performance characteristics between fencers and judo athletes of different levels of competitive success, such differences did occur in taekwondo athletes. The physical performance test has been used widely in talent system and provides general information on the level of fitness for the athletes in sports. The findings of this study could be useful input for talent identification in taekwondo athletes, especially to define and distinguish between them in different groups.

2.3 Motor coordination

Researchers have highlighted the contribution of motor coordination in certain sports (Vandorpe, 2012; Deprez et al., 2015; Mostaert et al., 2016) and have shown the importance of motor coordination on development in specific sports. Only a few studies (Pion, Fransen, Lenoir & Segers, 2014) used field-based tests to define motor coordination scores, especially among the elite in combat sports. Therefore, the findings on the motor coordination in combat sport athletes could a true added value to the current literature in TID.

Based on the findings of our study, young taekwondo athletes have better motor coordination scores compared to the other two combat sports, while, young judo athletes performed better than young fencing athletes. This could be explained by the nature of the combat sport, whereas judo uses the grappling technique and taekwondo uses the striking technique (Yoon, 2002; Arseneau et al., 2011; Franchini et al., 2011; Campos et al., 2012). Although this has not been studied explicitely, it might be that taekwondo relies more heavily on motor coordination than judo does.

Moreover, elite judo athletes performed better in two out of three motor coordination tests than sub-elite and drop out group. Meanwhile, the score for young fencing athletes is more similar to each group (medallist and non-medallist) and there were no differences between groups in motor coordination tests. Motor tests could not distinguish between athletes of different competitive level in judo and fencing. The fact that this was not the case does not necessarily mean that coordination is not an important factor. General motor coordination has been proven to be a valuable indicator of an athlete's potential for progression and is as such an important talent characteristic in skill-based sports such as artistic gymnastics (Vandorpe et al., 2012) and other combat sports (Sadowski, 2005).

Besides that, motor coordination was shown to be one of the factors that could distinguish young taekwondo athletes in different levels or groups. Previous studies indicated that elite Taekwondo athletes could turn and kick at high speeds (5.2m/s to 16.26m/s) and they generate a huge amount of striking forces (390.7N to 661.9N) without losing balance (Pieter & Pieter, 1995; Lee, Lee & Han, 2008). The athletes should have good motor ability in order to perform such movements or actions, if not they pose the risk of exposing themselves to injury or losing balance during the competition. It is an advantage to have an athlete that possesses good motor coordination skills as it can help them to transfer or learn new skills in a specific sport (Vandorpe et al., 2012).

2.4 Combat Sports

Based on the literature, it is possible to make a distinction between combat sport athletes according to their disciplines by the use of the anthropometric and physical fitness tests. According to Tabben et al., (2014), high-level judo, karate and taekwondo athletes tested before a continental event had different physical characteristics. The use of the two sets of measurements and the addition of the motor coordination component appear to provide the same output as previously mentioned. The same generic test battery showed that it was possible to orient athletes towards different sports (Pion et al., 2015) as well as to sports that are to a certain extent similar to each other, like martial arts, karate, judo and taekwondo (Pion et al., 2014).

However, there is little information about the effectiveness of those methods in making comparisons between different levels of achievement in combat sport athletes. This study seeks to find additional information on discriminating factors that might apply to this field of study.

Anthropometric characteristics become the most important measurement as a baseline reference in the selection process in combat sports. Previous studies have shown that high performance taekwondo athletes and fencers are taller than athletes with lower performance levels. Taekwondo athletes have a lower amount of fat percentage (Marković, Misigoj-Durakovic & Trninic, 2005) and fencers are more slender with wide shoulders and thinner waists (Ochoa, Gutiérrez, Margain, 2013). Body fat percentage for world-class male judo athletes is lower than 10% and becomes even lower in those that are better ranked (Franchini et al., 2011). Anthropometric components might be an advantage for combat athletes as they allow them to better reach their opponents and thus, present an opportunity for scoring. This, however, has also been used as a guideline to define the technique and tactics of combat sport athletes. In judo, tall fighters preferred to use leg techniques, whereas hand techniques were preferred by short and medium-height fighters (Lech, Sterkowicz, & Rukasz , 2007).

Most combat sports require a mix of technique, strength, aerobic fitness, power and speed (Beekley, Abe, Kondo, Midorikawa, Yamauchi, 2006). These factors help to describe the uniqueness of each combat sport as compared to other combat sports. Based on the existing evidence, characteristics that discriminate elite from sub-elites are different from one combat sport to another. For example, in fencing anthropometric characteristics and leg power (Ntai et al., 2017) are critical for elite performance (although this was not corroborated in our own study). Medal-winning taekwondo athletes on the other hand excel in flexibility, power, speed and general coordination compared to their less successful counterparts. In the same line of thinking, profiles of combat athletes from different disciplines do not look very similar either at first glance. For example, judo athletes had higher levels of maximal strength compared to taekwondo and karate athletes, while karate athletes outperformed their counterparts from judo and taekwondo with respect to lower-limb power (Tabben et al., 2014). From the previous findings, there is no one performance characteristic that appears to be the dominant characteristic in combat sports, as in other sports such as the shot put, where size, strength and power are the most dominant characteristics found in athletes.

Nevertheless, the importance of motor coordination has been demonstrated for performance prediction (Pion et al., 2015) as well as for sports orientation. The importance of motor coordination characteristics was also supported in previous studies in combat sports such as taekwondo (Sadowski, 2005), judo (Manolaki, 1990) and fencing (Schich,1979). Motor coordination characteristics should be the basic factor in sports, combat sports included. Seefeldt (1980) mentioned that if a basic level of motor coordination, expressed in fundamental motor skills was not acquired, children would encounter difficulties when trying to learn later motor skills that would lead to skillfulness and apply these to sports and games.

Overall, the combination of anthropometry and physical performance seems to be the main point in previous studies and as well as the current study. Perhaps the importance of motor coordination should also been highlighted as the most fundamental of all three factors mentioned. The descriptive findings in youth athletes would help to broaden our current knowledge especially in combat sports and later will lead to a better understanding on the baseline of combat sport athletes.

In conclusion, the first and second studies indicated the ability or effectiveness of the used generic test battery to discriminate among athletes between groups. On the other hand, the third study on fencers did not indicate any significant differences between groups. This could be an indication of the limitation of the generic test batteries. As a consequence, researchers decided to explore other possible factors that could contribute to distinguish between groups. Hence, motivation in the form of enjoyment were considered for the subsequent study. The study considered non athletic school children between the age of 8-11 years old. This is of interest because prior to the first three studies, there were little studies if any, on enjoyment to participate in sports or physical activity.

2.5 Enjoyment

The Differentiated Model of Giftedness and Talent (DMGT) by Gagné (2004) is a combination of various factors that support the developmental process of giftedness into talent. Gagné listed several factors such as natural abilities, skills, intrapersonal characteristics, chance, environmental influences as key factors in talent development. Among the intrapersonal factors, Gagné included the motivational aspect that could be explained as needs, interests or values. Based on his model, motivation might be a potential aspect to be highlighted and expand the knowledge about motivation, in the context of talent identification. Given that participation in sport activities is a prerequisite for talent identification, we studied the possibility that enjoyment can help children to participate in sport.

According to the Self-Determination Theory (Ryan & Deci, 2000), children who participate in sports simply because they enjoy doing so, are autonomously motivated and will participate more in sports than theirs peers who participate because they feel pressured to do so. In this dissertation (Study 4), we found that children with a profile of relatively high-levels of physical performance and enjoyment demonstrate higher levels of sports participation. Nevertheless, children's fitness levels may be more decisive in terms of sports participation than their enjoyment levels. From our study, enjoyment in the execution of motor tasks, as well as performance in motor tasks, is related to sport participation. Enjoyment will motivate the children to become involved in sport or physical activity more, and with the right guidance they can develop or maximize their talent. This will increase the talent pool of young athletes and in the other hand the quality of the talent pool should also improve.

In spite of the presence of this factor in the model of Gagné, only very little attention has been paid to this factor in the context of talent identification in the past (Reilly, Williams, Nevill & Franks, 2000; Deshaies, Pargman, & Thiffault, 1979). However, in the review by Issurin (2017) motivation is a factor that is often reported by elite athletes in retrospective studies. A high degree of intrinsic motivation appears to be crucial for the attrition to training throughout the athletic career. In spite of this importance, motivation is not often included in standard test batteries for the identification of young talents (Vaeyens et al., 2008). The motivational aspect should be considered as a factor of sport involvement among youngsters, and perhaps it can also be included in the talent system to ensure that the young athletes especially will perform their best in activities that are more enjoyable for them and thus decrease the drop-out rates among athletes in general.

3. Methodological considerations in TID research

The studies reported in this dissertation attempted to directly link test profiles (anthropometric, physical fitness, motor coordination) at a given moment in time, and medal counts in a retrospective follow-up design. Especially when the moment of winning medals lies several years in the future compared to the timing of the tests, a strong design for the evaluation of 'potential' is available. This design is different from the comparative studies, in which attributes of athletes of different levels are compared to each other at a given moment in time. Factors that are found to discriminate between performance levels are then generally considered as 'important for talent identification'. However, this assumption does not take into account the dynamics of development in young athletes. Key characteristics do generally not develop linearly, among others as a result of maturational processes, nor is their importance stable throughout the athletic development years (Vaeyens et al., 2008).

Another, but related consideration concerns the definition of 'elite' in talent identification research. Many studies use different criteria to define 'elite' and 'non-elite' as was the case with many other studies (Aziz, Tan & Teh, 2002; Krstulović, Žuvela & Katić, 2006; Pion et al., 2015) where for example the coaches' opinion, or the admission to a Top Sport School based upon actual performance and / or sport specific tests is used to define the level of their athletes. In many other studies 'elite' and 'sub-elite' are used as a label to discriminate the better half of a group of athletes from their weaker counterparts, even if the 'elite' might not be successful at international level (Marković, Mišigoj-Duraković & Trninić, 2005; Pion et al., 2014). We used objective parameters of individual competitive success, namely obtaining medals, as the main discriminator between elite and sub-elites. Medals are one of the most visible expressions of one's athletic potential, and after each major international championship medal rankings are used to demonstrate the success of high performance nations. Although relating non-sport specific testing to actual performance level many years late results in the challenge to document all factors and processes that might have influenced the development from giftedness into talent (Gagné, 2004), it remains a straightforward and strong test for the value of such a test battery.

A third methodological consideration is inherent to research in elite athletes. Elite athlete's populations are by definition very small in numbers and this makes it difficult to gather information that can be analysed by means of the 'classical' statistical methods. By using a reference sample of well-trained young athletes to convert raw scores of the taekwondo athletes in the third study into z-scores, the statistical issue of low sample sizes, and influences of age and gender, can be avoided. A z-score positions an athlete on the Gauss-curve of his age- and gender matched peers, and these z-scores can be pooled over gender and age to enable the use of parametric statistics. The z-score method has been implemented by Matsudo (1996) to detect exceptional scores for volleyball and basketball players. His system was based on the z-profile of talented sportsmen compared to the z-profile of elite players in the national team in certain sports. Pion (2015) applied the z-score strategy to make a new score as a baseline in his talent system. Similarly, Kiphard and schilling (2007) adapted the z-score method and recalculated it into the motor quotient score (MQ) and later by Ahnert, Schneider, and Bös (2009) who aimed positioning children for motor coordination. Using that same reference population, a z-score on a given test, obtained by any elite athlete, can be reconverted into an actual performance, i.e. a raw score again. This is highly desirable from the perspective of the coach, for whom a z-score is far from informative in relation to his daily coaching responsibilities. Using this approach, the z-score would have given a new score that we can use as a baseline on talent selection and managed to make a better prediction of athletes in the future. This method is not just applicable when dealing with small numbers of sample but also with a large sample size. A potential caveat of this technique is the assumption that the development of relevant talent characteristics is a linear process before, during and after puberty. While this assumption holds for aspects of general motor coordination (e.g. Vandorpe et al., 2012), biological maturation is known to affect discrete aspects of physical performance and anthropometry in a non-linear manner (Philippaerts et al., 2006). This should still be taken into account during the interpretation of the reconverted z-scores in the context of talent identification.

4. Multidimensionality of talent development

Building upon the results of our third study on young fencers, it is clear that an exclusive focus on anthropometry, physical performance, and motor coordination with the aim of talent prediction has its limitations. Other characteristics might play a more prominent role in the development of gifts into talent. In line with the DMGT model, Gagné (2004) suggested various factors and domains, one of the them are motivational factors which fit in the intrapersonal catalysts. In our final study, we only touched on the motivational basis (enjoyment) of TID in a superficial way and this was the limitation of this study. Basically, this was an attempt to explore to what extent attitude towards given activities could potentially contribute to TID. This study indicated that level of enjoyment (motivational) has a positive relationship with physical participation in organized sports and somehow show the importance of motivation in sport participation.

Instead of solely using the generic test batteries, other factors should have been included that may have had an influence on athlete performance and such factors should have been taken into consideration, whilst the development or improvement of the talent system was taking place. Apart from the use of physical performances, Gagné (2004) suggested that the multidimensional aspects of the model included various factors and domains such as social economic status, motivational, technology and intellectual. The information gained from the fourth study of this dissertation has already given an idea on the relation between motivational and physical activity which can be considered to that of another level of research to determine the importance of motivational factors in the talent programme. Perhaps, the motivational factor might help to decrease the drop-out rate among athletes and provide a source of valuable information to the coaches or researchers as a means of searching for the talented young athletes in the future.

As we have observed in the third study, there were no differences among young elite fencers between medallist and non-medallist groups. Using or adding sport specific test there will be a gateway to differentiate among fencers of different competitive level and this can then produce a clear profile, especially among the elite athletes. In this way, the most discriminating indicators can be found for identifying potential talent (Issurin, 2017). Previous studies were successfully conducted in tennis (Roetert, Brown, Piorkowskil, & Woods, 1996), soccer (Reilly et al., 2000), water-polo (Falk, Lidor, Lander, & Lang, 2004) and volleyball (Lidor, Hershko, Bilkevitz, Arnon & Falk, 2007). In fencing, many different physical profiles are present in the world rankings. In addition, the more characteristics that are related to expert performance, the more opportunities for compensating for one or more relatively weaker attributes. For example, tall fencing athletes have the advantage of longer arms, enabling them to compete with a greater action radius compared to smaller athletes. Taller athletes are assumed to be slower however, due to their greater moments of inertia when compared to smaller fencers. This is a clear example of a 'compensation phenomenon', meaning that it is not necessary for an athlete to excel in each and every attribute that could be related to elite performance.

Another component that could be implemented to differentiate combat sports athletes is the executive functioning (EF). This component is not a uniformily defined term but generally used to describe the cognitive processes that regulate thought and action (Friedman et al., 2008). Executive functioning mainly focuses on areas like problem solving, planning, sequencing, multi-tasking, cognitive flexibility and ability to deal with novelty (Chan, Shum, Toulopoulou & Chen, 2008). Researchers have suggested that expert players are superior in EF compared with novice player in soccer (Ward & Williams, 2003), basketball (Allard, Graham & Paarsalu, 1980) and field hockey (Starkes & Deakin, 1984), among others because EFs are considered to subserve processes like decision-making, sustained attention. The impact of general executive functions on the combat sports athlete is largely unknown (Voss et al., 2010) and this component could give an additional input on the level of executive function among combat athletes which related to their sport (decision making and problem solving).

5. Implications

This dissertation results in several implications for the scholar and the coach. First, the importance of standardised test batteries including anthropometry, physical performance, and motor coordination in talent identification is supported in combat sports. Especially the role of motor coordination as an indicator of 'progress potential' is worthwhile, because it can be used even before sport-specific skills have been practiced enough to be reliably be used in a test battery. The limitation of this approach, as evident from the analysis on the young fencers, does not necessarily mean that these tests are useless, but rather that they do not have to be repeated over and over again in all sports. For example, it is generally accepted that coordination tends to stabilise once the child has reached the age of 7-8 years, and that it is very difficult for the young athlete and his/her coach to improve that basic level from then on (Vandorpe et al., 2012). While such a generic test battery capable of identifying the 'better movers' might thus be sufficient in the early stage of the development process, gradual addition of more specific test will be necessary. For example, in youth soccer, endurance can be evaluated by means of a standard field test like the Cooper test (Cooper, 1968) or the PACER (Cooper Institute for Aerobic Research, 2000). Endurance demands in adolescent soccer are however insufficiently covered by these protocols, and an intermittent endurance test like the YoYo (Bangsbo, 1994; Castagna et al., 2006) might replace the former tests. Similarly, in combat sports test batteries the generic motor coordination tests should gradually be replaced by sport-specific technical tests. A generic test like the KTK (Kiphard, & Schilling, 2007) provides a good estimate of the basic level of coordination, which is the cornerstone of sport specific skill. In addition, this task is considered relatively unaffected by sport specific training (Vandorpe et al., 2012). There is however no need to re-evaluate this attribute over and over once the young athlete has proven to score sufficiently on this characteristic.

Related to the issue above, and in line with the DMGT model, other characteristics need to be included if we want to make our predictive models stronger. So far a very limited number of studies take into account all factors that are proposed in Gagné's model (2004). Next to the merits, this dissertation highlighted the limitations that existed with regards to the parameters that were used to distinguish the combat sport athletes in their different levels, specifically in the sport of fencing. There might be other factors that should have been included if one would like to obtain more insight in the possible differences between fencers of different performance levels. In this respect, Flemish Top Sport Schools have started to add more specific tests to the general Flemish Sports Compass, for example the evaluation of binocular depth vision and an adapted sprint shuttle run for young fencers. Unfortunately, the sample size of these tests is still too small to allow reliable analysis on their predictive power in the context of this dissertation.

Another limitation is that we did not focus much on maturity, a factor that can affect anthropometry dimensions as well as physical performances. Maturity affect needs to be considered in competitive sports because younger athletes who are less developmentally mature may encounter disadvantages in terms of functional capacities when compared to more developmentally mature athletes (Malina, et al., 2004). In this dissertation, maturity was measured in the Study 2 and Study 3 only, but we did not take care maturity in the systematic way. Skeletal maturation is recognised as the best method for assessing biological maturity states and an ideal marker of maturity, as its maturation spans the entire growth period (Malina, 2011). However, it is possible to identify maturity indicators from body dimensions, particularly stature (Unnithan, White, Georgiou, Iga, & Drust, 2012). Research has demonstrated that early matures can possess greater muscular strength (Vaeyens et al., 2005) and speed (Malina, Eisenmann, Cumming, Ribeiro & Aroso, 2004) over their late developing peers. Since chronological age and biological maturity rarely progress at the same degree (Vaeyens et al., 2008), it is useful to consider the maturity effect when aiming to distinguish combat sport athletes of different levels.

Next to the maturity issue, the Relative Age Effect (RAE) can also affect performance on many tests included in batteries for TID. Youth athletes born in the first quarter of a selection year have a natural advantage over their later born peers because they are older and thus by definition have more chance to be more advanced in their biological development (Delorme, Chalabaev, & Raspaud, 2011). These effects have been observed in a wide variety of studies showing RAE in professional athletes. The REA showed that elite athletes who were born early in the competition year had a greater representation than those who were born later in that year for certain sports such as baseball (Grondin & Koren, 2000), junior ice hockey (Baker & Logan, 2007), soccer (Musch & Hay, 1999) and youth handball (Schorer, Bakaer, Lotz & Busch, 2010). In terms of combat sports, the REA was not found in taekwondo and boxing, but was found in heavier Olympic judo athletes (Albuquerque et al., 2013) and Olympic wrestlers (Albuquerque et al., 2014). Judo and wrestling are grappling combat sports and seem to require higher anaerobic energy demand than striking combat sports such taekwondo and boxing (Yoon, 2002; Arseneau et al., 2011; Franchini et al., 2011; Campos et al., 2012). These differences in nature between combat sports may be the possible explanation that RAE is observed in a sport in which body size and strength play key roles, as Delorme et al., (2010) hypothesized.

Similarly, environmental factors like the socio-economic situation and birth place were not taken into account in this dissertation. For example, the impact of the place where the athletes are born has been investigated in several of studies such as professional baseball, basketball, golf and hockey (Cote et al, 2006), football (Macdonald, Cheung, Cote & Abernethy, 2009) and junior ice hockey (Baker & Logan, 2007) for male athletes. From these studies, male athletes who were born in cities of less than 500,000 people and female athletes who were born in cities of less than 1,000,000 people (for soccer) and 250,000 (for golfers), tend to attain higher levels of sport competition than athletes who were born in larger cities.

The findings from this study showed that it is possible to distinguish between taekwondo and judo athletes and their levels of achievement and participation, but this, however, is not so with the fencing athletes. We suggest that taekwondo coaches concentrate more on the speed and explosivity components in their training programme, as we have observed that these physical fitness components are distinguishable between the elite and non-elite athletes. Motor coordination should also be included in taekwondo training as this seems to be the fundamental aspect needed for the development of good level taekwondo athletes. For the judo coaches, findings from this study proposed that the anthropometric characteristics are important criteria in the selection process. Judo is a grappling combat sport and judo athletes will need to throw or takedown their opponent on the ground which depend on effective techniques. Based on the anthropometric characteristics, coaches should define the most efficient technique for their athletes, which also have been reported in previous study (Lech, 2007). The fencing study showed no significant differences between the group in three of the parameters, and one possible explanation might be that the fencers in this study have acquired the fundamental motor patterns necessary to be successful. Above this level, or proficiency barrier (Seefeldt, 1980), coordination does no longer discriminate in this particular sport.

Due to the time constraints and the objective of this study, we have not concentrated on the training attributes. In the previous studies, training have shown a significant effect to physical performance components in combat sport athletes (Callister, Callister, Fleck & Dudley, 1990; Ball, Nolan & Wheeler, 2011: Tsolakis, Bogdanis, Vagenas & Dessypris, 2006). The information regarding training information would be an additional information that could help a better understanding on combat sport athlete's development and the effectiveness of their training program. Moreover, as part of the date is from an on-going study, the lack of data on the training schedule, has made this one of the limitations in this study.

Nevertheless, another factor that should also to be considered is physiology factor. Previous researchers (Matsushigue, Hartmann & Franchini, 2009; Cerizza & Roi, 1994; Franchini et al., 2011) have highlighted their findings in physiology aspects that related to combat sport athlete's performance. This method will have to use a lab equipment that required a lot of time or money to make it possible. Therefore, this method might be practical in the higher-level groups of athletes (e.g. Olympic) and should be a difficult approach in the talent detection or talent identification due to the numbers of athletes and time constrains.

6. General Conclusion

This dissertation underlines the importance of generic, i.e. non-sport specific test batteries to be used in Talent Identification research. Test scores generally have a predictive value with respect to competition performance of the athlete in the future. Especially the inclusion of the evaluation of non-sport specific motor coordination is promising and in line with similar studies in other sports like gymnastics (Vandorpe et al., 2012), volleyball (Pion et al., 2015), or soccer (Deprez et al., 2015). Our results corroborate the notion that general motor coordination allows to predict the 'developmental potential' an athlete possesses and is relatively independent of training history in sport specific skills.

However, the absence of such differences in our third study indicates that the approach of focusing on anthropometry, physical performance, and motor coordination alone has its limitations, and is probably not transferrable without modification to other sports.

There is no doubt that, in line with the factors in Gagné's (2004) Developmental Model of Giftedness and Talent, many other factors play a part in an athlete's development, and as a consequence, could improve the predictive value of a given test battery. Extrinsic factors (coaches, accommodation, quality of the developmental program) as well as intrinsic characteristics (psychological traits, motivation) also play a part in this process. The fourth study indicated that 'enjoyment', in combination with motor competence, can positively affect a child's sport participation (De Meester et al., 2016) but underlines the need for continuous investigation of all these characteristics in a multidimensional approach.

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SUMMARY

This dissertation builds upon previous research in the context of the Flemish Sports Compass (FSC) that aimed at discovering talent characteristics in youth athletes. This work used a similar scientific approach but focuses on three combat sports; Judo, Taekwondo and Fencing. Three groups of characteristics are evaluated in this study in order to develop a talent identification model in combat sport. Anthropometric, physical performance, and motor coordination attributes among combat sport athletes will be related to different levels of achievement in competition. Three out of four studies (study 1 until study 3) are using a similar methodology: coupling of their competitive performance level to their scores on a generic test battery some years earlier.

In the first study, 22 trained male judo athletes (under 14) were tested and from the total of 22 judo athletes, six were categorised as elite, ten were sub-elite and six of them were considered as drop out. The purpose of the study was to estimate the future performance of young male judo athletes with predictive statistical models. Anthropometric characteristics positively distinguished between elite, sub-elite and dropout, whereas there no significant differences in physical performance and motor coordination attributes.

The second study investigated whether there are differences between elite and non-elite taekwondo athletes in the three parameters. In this study, 98 taekwondo athletes between 12 and 17 years were tested and 18 were categorised as elite and the rest were categorised as non-elite. This study identified characteristics that differentiate between elite and non-elite taekwondo athletes. Elite scores better compared to the non-elite group and MANOVA analysis showed a significant difference between the two groups on fat percentage, sprint speed, explosivity and general body coordination.

In the third study, 83 young fencers between 11 and 16 years old were tested using the same test batteries as in study 1 and study 2. The aim of this study was to identify anthropometric, physical performance and motor coordination characteristics that discriminate medallist and non-medallist fencers. From the 83 young fencers, 21 were grouped as medallist and 62 were grouped as non-medallist. Apart from the anticipated effects of maturity and calendar age on anthropometry, physical performance, and general coordination, no differences between medallist and non-medallist athletes were observed.

Finally, a fourth study was conducted to investigate the relationship of the motivational factor of enjoyment and sport participations among youngster. This study aimed to prepare for future studies looking into other factors that might be important in the context of talent identification. This study showed that there was a relationship between the combination of performance and enjoyment and sport participation in organized sports among children with different profiles.

Altogether, our findings indicate that it is possible to distinguish judo and taekwondo athletes from different levels by using anthropometric, physical performance and motor coordination tests, although, this was not so in the case of fencing. Despite the fact that successful results were used to discriminate the combat athletes with the three measurements, it also showed the limits of this method as was the case in the fencing study. Therefore, further research was conducted in order to investigate associations between the motivational aspect (enjoyment) and participation in sports among the youngsters. This could serve as a future gateway to explore the role of this attribute in young elite athletes.

SAMENVATTING

Het huidig doctoraat bouwt verder op voorgaand onderzoek in het kader van het Vlaams Sportkompas (VSK), dat gericht was op het identificeren van talentkenmerken bij jeugdatleten. Dit werk gebruikte een vergelijkbare wetenschappelijke benadering met het VSK, maar richtte zich op drie vechtsporten: judo, taekwondo en schermen. Om een talentidentificatiemodel in de vechtsporten te ontwikkelen, werden binnen deze studies antropometrische, fysieke en motorische coördinatie karakteristieken bij vechtsporters geëvalueerd en gerelateerd aan verschillende competitie rankings. De eerste drie studies gebruikten een gelijkaardige methodologie, waarbij het competitieniveau van de atleten werden gekoppeld aan de scoes op een niet-sport specifieke testbatterij.

In de eerste studie werden 22 getrainde mannelijke judoka (< 14 jaar) getest, onderverdeeld in zes elite, tien niet-elite en zes drop-out atleten. Het doel van de studie was om de toekomstige prestaties van jonge mannelijke judosporters in te schatten door predictieve statistische modellen.

De tweede studie onderzocht de discriminerende kenmerken tussen elite en niet-elite taekwondo-atleten. In deze studie werden 98 taekwondokas(18 elite en 80 niet-elite) tussen 12 en 17 jaar getest. De elite groep had significant betere resultaten voor vetpercentage, sprintsnelheid, explosiviteit en algemene lichaamscoördinatie in vergelijking met de niet-elite groep (MANOVA).

Het doel van de derde studie was om de discriminerende kenmerken te identificeren tussen medaillewinnaars en niet-medaillewinnaars in het schermen. 83 jonge schermers tussen 11 en 16 jaar oud werden getest, waarbij 21 werden gecategoriseerd als medaillewinnaars en 62 als

niet-medaillewinnaars. Afgezien van de verwachte effecten van maturiteit en kalenderleeftijd op de antropometrische, fysieke en algemene coördinatie, werden geen verschillen waargenomen tussen beide groepen.

Tenslotte werd een vierde onderzoek uitgevoerd naar de relatie tussen motivatie (plezierbeleving), prestatie en sportparticipatie bij jongeren. De resultaten toonden aan dat er een verband is tussen prestatie, motivatie en sportparticipatie in georganiseerde sporten bij kinderen met verschillende profielen. Hierdoor kan gesuggereerd worden dat motivatie een waardevolle aanvulling kan vormen bij de huidige niet-sport specifieke testbatterij in de zoektocht naar talent.

Samengevat wijzen de bevindingen uit dat het mogelijk is om judoka en taekwondoka van verschillende prestatieniveaus te onderscheiden op basis van antropometrische, fysieke en motorische coördinatie kenmerken. Deze significante verschillen waren echter afwezig bij de schermers, wat aantoont dat deze methode gelimiteerd is. In de toekomst zou het gebruik van een multidimensionale testbatterij zinvol lijken, waarbij o.a. een associatie wordt gelegd tussen motivatie (plezierbeleving) en fysieke kenmerken in de zoektocht naar sportief talent.

List of Publications and Presentations.

<u>Publications</u>

Norjali, R., Torfs, M., Mostaert, M., Pion, J., & Lenoir, M. (2017). Predicting judo champions and medallists using statistical modelling. *Archives of Budo, 13*, 161-167.

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Presentation

Norjali Wazir, M.R.W., Mostaert, M., Pion, J., Lenoir, M (2018). Anthropometry, physical performance, and motor coordination of medallist Aad non-medallist young fencers. Oral presentation at European College of Sport Science (Dublin) 06/06/2018.

Norjali Wazir, M.R.W., Pion, J., Deconinck, F., Mostaert, M., De Meester, A. and Lenoir, M (2017). Do children like what they do? Association between preference and performance on a motor task. Poster presentation at North American Society For The Psychology Of Sport And Physical Activity (San Diego, USA) 05/06/2017.