Starting and specialisation ages of elite athletes across olympic sports: An international cross-sectional study

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RESEARCH ARTICLE

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Starting and Specialisation Ages of Elite Athletes across Olympic Sports: An International Cross-sectional Study

Veerle De Bosscher, Kari Descheemaeker, and Simon Shibli

ABSTRACT

Talent development models are the frameworks that guide sports stakeholders in developing potential athletes, within which early specialisation and diversification remain contradictory strategies. This paper presents new insights into the starting and specialisation ages of world-class athletes in various Olympic sports. A total of 2,838 athletes from 13 nations and 44 Olympic sports were included in this study. The results show that world-class athletes started with their current sport at the age of 10.6 (±5.3) and decided to focus on this sport at the age of 15.6 (±5.0), with obvious variations in these ages across different sports. The study showed a moderate relationship between athletes' starting and specialisation ages (r = 0.639), which demonstrates the variable duration of the multiple sport sampling period. This period, during which athletes pursue a variety of sports, lasts 4.9 years on average. There is a high degree of variation among different athletes in starting and specialisation ages, even within the same sport. All sports in the study can be classified into five categories based on a combination of their starting ages (early/intermediate/late) and specialisation ages (early/intermediate/late). The Developmental Model of Sports Participation provides the age guidelines for the categories. The five categories contain (I) early specialisation sports, (II) intermediate starting and specialisation sports, (III) late specialisation sports, (IV) late starting sports, and (V) late starting and late specialisation sports. The study concludes by proposing that there is a need for sport-specific talent development models with increased attention to each sport's starting age, sampling period, and specialisation age.

Keywords: Diversification, early specialisation, Olympic sports, sport sampling, talent development.

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I. Introduction

Many countries strive to achieve success in major sports events, such as the Olympic Games, World Championships, and Continental Championships. During the last few decades, the global battle for sporting medals has intensified (De Bosscher & Shibli, 2021; De Bosscher *et al*., 2015), and the desire of national sporting organisations (NSOs) to develop world-class athletes has increased. Their talent identification and development strategies are required to transform talented youngsters into top-level performers. However, how exactly NSOs can develop emerging sporting talents with elite potential is a contentious subject of debate between researchers.

Many national talent systems have focused on the early identification of talent, whereas nurturing and developmental strategies have gained less attention (Martindale *et al*., 2005). As a result, over the last four decades, several research and practice-based talent developmental models have been presented in the literature: for example, the transition model of Bloom (1985), the Long-Term Athlete Development Model (Balyi, 2001), the Holistic Athletic Career model (Wylleman & Lavallee, 2004), the Developmental Model of Sport Participation (Côté *et al*., 2007), the Attraction, Retention/Transition, and Nurturing Model (Sotiriadou *et al*., 2008), and the Foundation, Talent, Elite, and Mastery Model (Gulbin *et al*., 2013). All these models show a continuation of different stages ranging from starting in a sport to retirement after an elite career. However, there is a lack of empirical research about these models at a sport-specific level. More precisely, there is limited knowledge on starting and specialisation ages and the subsequent adaptation of talent development models in a sport-specific context. Therefore, more sport-specific research is needed to improve our understanding of talent development processes. This paper contributes to addressing this scarcity of knowledge.

The research is guided by the Developmental Model of Sports Participation (DMSP) (Côté *et al*., 2007). This model was chosen because it shows different sports participation trajectories linked to the characteristics of a sport. Moreover, this model provides age ranges within the trajectories, which can be

used to compare sports and their specific pathways. The DMSP provides two pathways to elite sporting success. The first pathway targets elite performance through early specialisation, whereas the second uses multiple sport sampling strategies, also known as diversification, to target elite performance. Both pathways start with an entry into a sport at around six years of age. The early specialisation pathway immediately focuses on a single sport with high levels of deliberate practice and low levels of deliberate play. By contrast, the diversification pathway promotes involvement in several sports and focuses on deliberate play activities during the first stages of development. At the age of 12, in both pathways, athletes specialise in one sport and increase the amount of deliberate practice.

Deliberate practice consists of a focus on a single sport, with long training hours and high numbers of repetitions (Ericsson *et al*., 1993). Deliberate play can be seen as the opposite, with a stronger focus on enjoyment during the activities. Deliberate play activities have considerable similarities with a sport but lack a formalised structure and do not pay specific attention to skill development (Côté & Hay, 2002). These playful activities are thought to increase athletes' intrinsic motivation. While the effectiveness of deliberate practice is shown in many studies (Macnamara *et al*., 2016), other research has shown that extensive engagement in playing activities in the early phases of involvement led to greater success (Côté & Hay, 2002; Hornig *et al*., 2016).

Deliberate practice and deliberate play are both present in the two developmental pathways of the DMSP. Yet, as they represent two opposing concepts, the choice on which to focus depends on the preferred pathway. Following the deliberate practice theory (Ericsson *et al*., 1993), the idea of intensive training with an early start and early specialisation has become increasingly common. The deliberate practice theory states that success is the result of intense practice performed over a minimum of 10 years (10,000 hours). To accumulate this number of hours, an early specialisation pathway seems advantageous. According to Baker *et al*. (2009), early specialisation consists of the combination of four key characteristics: (1) there is an early start in organised sport; (2) with an early focus on one sport only; (3) the early training is of high-intensity; and (4) there is involvement in some form of competitiveness. A decade after the rise of the deliberate practice theory, the early specialisation approach was strongly criticised, as it could have negative consequences for a child's long-term physical and psychological health (Baker *et al*., 2009; Horton, 2011; Malina, 2010) such as an increased injury risk, limitations to overall development (Mosher *et al*., 2022), and an increased risk of dropout in further sport participation (Malina, 2010). However, there are also studies that state that there is no evidence that early specialisation leads to overuse injuries and negative developmental aspects (Mattson & Richards, 2010). Regardless, it has been demonstrated that, at some point, an athlete will have to start specialising and develop into a high-performing international athlete (Côté *et al*., 2007; Vaeyens *et al*., 2009). It is not yet substantiated scientifically at what point this specialisation should be initiated in every sport (DiSanti & Erickson, 2019).

Over the last two decades, increasing numbers of authors have called for multisport promotion and to promote early diversification approaches (Baker *et al*., 2009). Research has shown that participating in a variety of sports did not disadvantage athletes in acquiring expertise in their main sport (Côté *et al*., 2007). Moreover, early diversification is linked to positive youth development and long-term involvement in sports that is shown to lead to greater future success in the main sport (Bridge & Toms, 2013; DiSanti & Erickson, 2019; Güllich & Emrich, 2006a, 2006b; Güllich *et al*., 2022). Güllich *et al*. (2022) concluded that adult world-class athletes had a later start, engaged in more multisport practice, and had less main sports practice than their national-class peers. However, a gap in this research was that there was no consideration of sport-specific differences, despite an earlier study (Güllich, 2007) demonstrating that athletes in different sports have different starting ages.

In general, sport-specific age differences can be observed at three different levels: the specialisation ages, the starting ages, and the duration of the sampling period. The difference in specialisation age can partly be explained by a preference for training methods and, therefore, a preference for one of the two pathways of the DMSP: early specialisation or early sampling. Balyi (2001) recognised that some sports, such as gymnastics, figure skating, diving, and table tennis, require early specialisation, with early intensified training and sometimes less focus on fun and enjoyment. Two sport-specific parameters show the necessity for early specialisation. First, early specialisation is desirable in sports with clearly defined requirements, such as the desire for a specific physique where athletes are preferably lean and small, for example, figure skating (Mattson & Richards, 2010). Second, early specialisation seems to be the superior strategy in sports where peak performance occurs before biological maturation (e.g., rhythmic gymnastics and women's figure skating) (Deakin & Cobley, 2003; Law *et al*., 2007; Starkes *et al*., 2014). Lastly, DiSanti and Erickson (2019) conclude that early specialisation is more frequently seen in individual sports than in team sports.

Besides the varying specialisation ages, there is a second difference in the developmental pathways of different sports, namely the onset of training in the sport. It is generally accepted that in some sports, such as gymnastics and soccer, an early starting age is required (Caine *et al*., 2001; Ford *et al*., 2008; Helsen *et al*., 2000; Ward *et al*., 2004). Nevertheless, in other sports, an early start does not seem to be a precondition

for subsequent international success (Güllich & Emrich, 2006a).

A third, yet insufficiently researched, difference could lie in the duration of the sampling period. This means the timeframe in which athletes explore their main sport as well as taking part in other sports. There is a lack of knowledge on the sport-specific differences in the duration of the sampling period, as well as in the mix of different types of sports practised in this period. There is a call for research that summarises all possible age differences between sports and identifies how sport-specific developmental pathways should be applied. Additionally, earlier research has shown differences in peak performance ages based on gender (Allen & Hopkins, 2015). There is insufficient scientific data to analyse whether these gender differences are also apparent in the starting and specialisation ages.

Before we can draw general conclusions, we need context-specific and sport-specific research to provide detailed sport-specific guidelines concerning starting ages and specialisation ages (Côté *et al*., 2007). There is little empirical sport-specific data to guide the decision-making process in talent development. To address the identified data deficiency, this paper provides insights into the differences in starting and specialisation ages in various Olympic sports. The research is a modest but worthwhile contribution to the literature, as there is currently no investigation into the relationship between age and success. However, in this research, all athletes included in the study already had some degree of success and exhibited the highest levels of international sporting ability. Four research questions guide this study: (1) What are sport-specific starting and specialisation ages in world-class elite athletes? (2) Is there a relationship between an athlete's starting and specialisation age? (3) How can we classify sports according to their starting and specialisation ages? (4) How do sport-specific starting and specialisation ages differ by gender?

II. Methodology and Design

A. Design

A cross-sectional, retrospective design was used to collect data from an international sample of elite athletes. A standardised online questionnaire, entitled the 'Elite Sport Climate Survey', was implemented in 14 nations. The survey was part of a large-scale project of the Sports Policy Factors Leading to International Sporting Success (SPLISS) research group (De Bosscher *et al*., 2015) and this research is based on a secondary analysis of the primary data.

B. Data Collection and Procedures

The questionnaire was sent out to active elite Olympic athletes in 14 nations: Australia, Brazil, Canada, Denmark, Spain, Estonia, Finland, Belgium (Flanders and Wallonia), Japan, Netherlands, Northern Ireland, Portugal, Switzerland, and South Korea. It should be noted that the participating countries were a self-selecting sample of nations that showed an interest in elite sports development systems. To guarantee international comparability, the term 'elite athlete' was strictly defined to make sure that the sample consisted solely of world-class athletes. Two definitions were used:

1. Elite athletes are the Olympic athletes who are ranked in the world's top 16 or continental top 12 in their Olympic discipline, either as an individual or as part of a team.

OR

2. Elite athletes are the individuals who receive funding with the purpose of achieving success in at least one of the following senior competitions: the Olympic Games, the World Championships, and/or Continental Championships (De Bosscher *et al*., 2015).

The survey was sent to 8,495 elite athletes, from whom 3,142 responses (37%) were received. For data protection reasons, Australia decided not to share the sports disciplines of athletes; therefore, this country (208 athletes) was excluded from this sport-specific analysis. After data cleaning and removal of respondents who did not meet the criteria (e.g., non-Olympic disciplines), 2,838 athletes were included in the study. Our total sample was made up of 1,217 female athletes (43%) and 1,613 male athletes (57%) from 44 different summer and winter Olympic sports. In the sport-specific analyses, only the sports with 20+ respondents were included. Thirty-three sports (of which six are winter Olympic sports), representing a total of 2,642 athletes (93% of the usable sample), were included in the sport-specific analyses.

For every athlete, details about their nation, sport, and discipline were collected. The starting age was assessed by the question: "*At what age did you take up this sport for the first time?*" Additionally, the specialisation age was estimated by the question, "*At what age did you decide to concentrate solely on your current elite sport?*" This study does not cover the full picture of specialisation, including training volume and intensity. However, the data provide further insights into athletes' starting and specialisation ages at an international level.

A limitation of this paper is that the study used a self-reporting retrospective survey that required athletes to recall events that occurred up to 54 years ago. This technique is associated with a high potential for recall bias (Côté *et al*., 2005). However, earlier sporting studies have found retrospective questionnaires to be very effective for collecting objective information, such as age (Côté *et al*., 2005; Moesch *et al*., 2011).

C. Data Analysis

Analyses were carried out in SPSS v28. First, an overall analysis revealed the mean starting and specialisation ages of the sample. The mean diversification time, representing the time when athletes were exploring different sports, was estimated as the difference between the specialisation and starting age. Pearson's correlation coefficient was used to assess whether there were differences in the diversification time by measuring the linear relationship between starting and specialisation age.

Second, mean sport-specific starting and specialisation ages and their respective variances were computed and used to compare different sports. Further descriptive analyses were used to illustrate the differences between sports when combining starting and specialisation ages.

Third, two boxplots showing the differences in starting and specialisation ages across individuals were produced. These descriptive graphs demonstrate the variability of the data by visualising the median, quartiles, and outliers.

Finally, as earlier research has shown that in some sports, there are major differences in age by gender, a pairwise comparison of males and females was made at a sport-specific level. Paired samples t-tests were used to identify the sports with significant gender differences in either starting age or specialisation age.

III. RESULTS

Athletes began with their sport on average at the age of 10.6 (±5.3) years and decided to focus solely on their current elite sport at the age of 15.6 (±5.0) years. In this sample, athletes practised their sport on average for 4.9 years before they focused exclusively on their main sport. Pearson's correlation coefficient shows only a moderate relationship between athletes' starting age and specialisation age ($r = 0.639$, $p < 0.01$). This finding shows that there are differences in the duration of the diversification period between different athletes and sports.

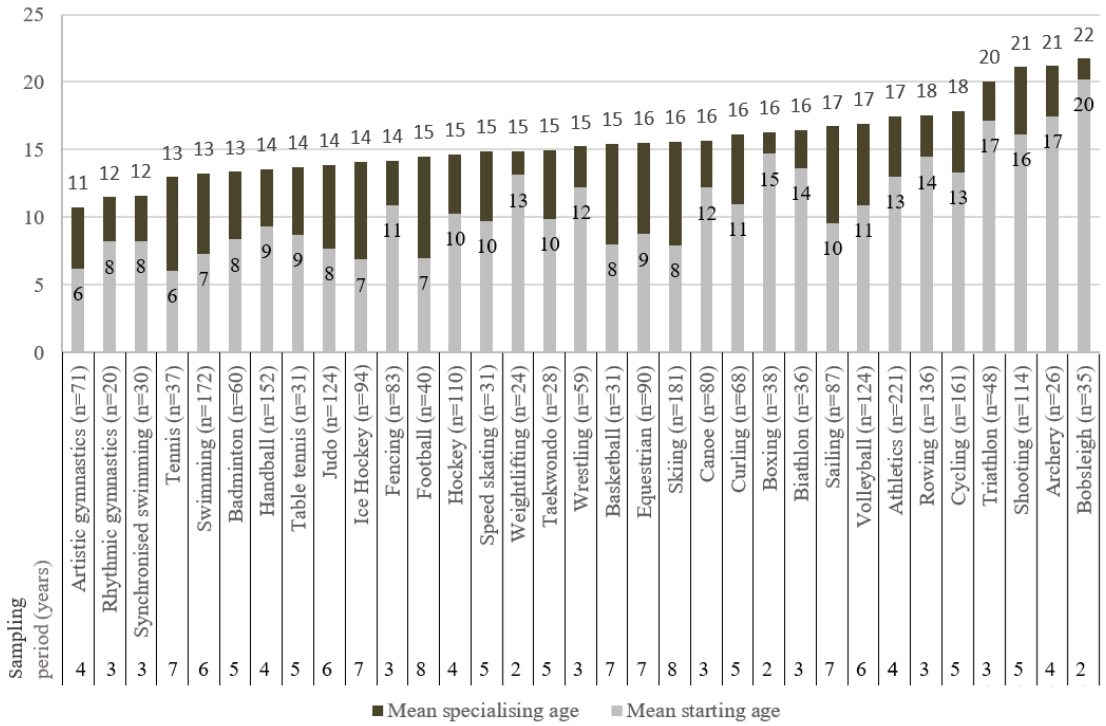

Fig. 1. Overview of the average age at which athletes started with their sport, the age at which they decided to concentrate on their current elite sport only, and the mean duration of the sampling period (sports with n>20).

Fig. 1 provides an overview of sports of the ages at which elite athletes started with their sport and the ages they decided to concentrate on their current sport only (which we take to mean 'specialise'). At the bottom of the figure, the mean sampling period in each sport is shown. The mean sampling period was estimated as the difference between the specialisation and starting age. The figure shows a high degree of variation between sports. The starting ages range from 6.0 years old in tennis and 6.2 in artistic gymnastics to 17.1 in triathlon, 17.4 in archery, and 20.2 years in bobsleigh. The specialisation ages vary from 10.7 years to 21.7 years. Athletes start to specialise the earliest in artistic gymnastics (10.7±4.1), followed by rhythmic gymnastics (11.5±1.7), synchronised swimming (11.6±3.5), and tennis (13±3.9). By contrast, athletes specialise in the latest in bobsleigh (21.7±2.7), followed by archery (21.2±10.8) and shooting

(21.1±7.4). In some sports (e.g. football, basketball, skiing), despite a relatively early start, athletes only specialise from the age of 15. The sports where athletes stayed the longest in the sampling period were skiing (7.6 years), football (7.5 years), basketball (7.4 years), ice hockey (7.2 years), and sailing (7.1 years). At the other end of the continuum, in some sports (e.g. bobsleigh, boxing, weightlifting), specialisation starts relatively shortly after athletes start with their sport.

To summarise the major differences between sports, in Fig. 2, all sports are classified into nine categories according to their mean starting and specialisation ages. The nine categories are based upon the age guidelines of Côté *et al*. (2007), who described a standard starting age being between six years old and 12 years old. Sports with a mean starting age either below or above this category can be described as early-starting or late-starting sports, respectively. A standard specialisation age, according to Côté *et al*. (2007), lies between 12 years old and 16 years old. Likewise, we can classify some sports as being early specialisation and others as late specialisation sports. We combine both age categories to classify sports into one of the nine categories, but in practice, all 33 sports can be grouped into a subset of five of the nine categories. The findings identify artistic gymnastics, rhythmic gymnastics, and synchronised swimming as early specialisation sports (category I). Category II shows sports which fall into the starting and specialisation age ranges, as mentioned by Côté *et al*. (2007). Curling, sailing, and volleyball have an intermediate starting age but are characterised by a late specialisation age (category III). By contrast, canoe, wrestling, and weightlifting are late-starting sports but have an intermediate specialisation age (category IV). Nine Olympic sports (bobsleigh, archery, triathlon, shooting, cycling, rowing, athletics, biathlon, and boxing) are characterised by having both a late starting age and a late specialisation age (category V).

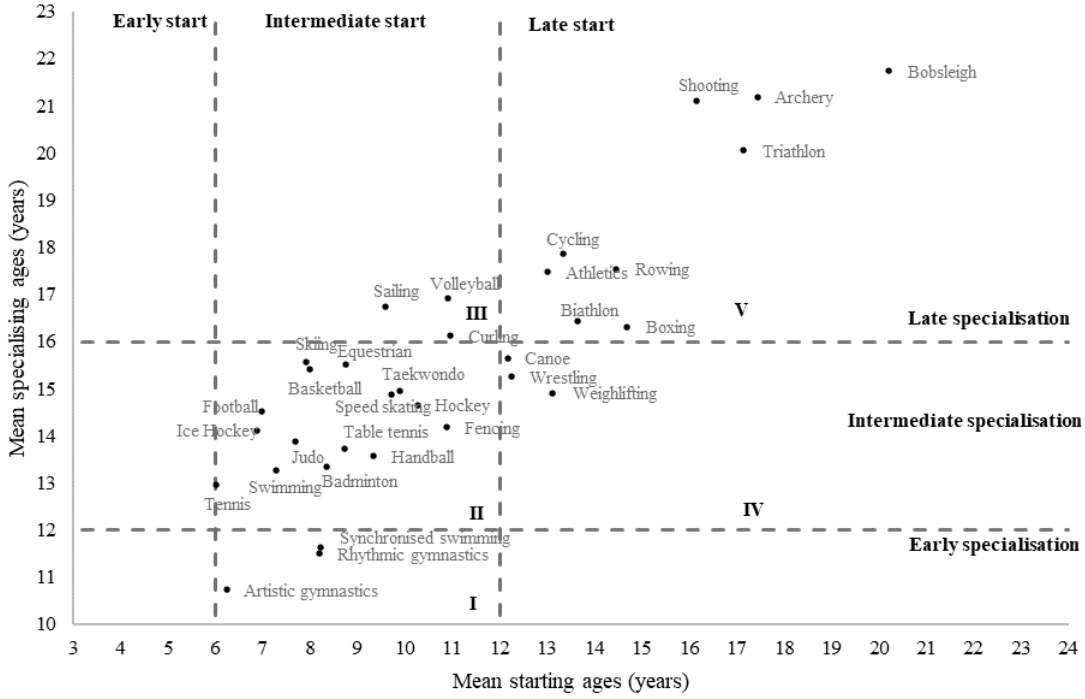

Fig. 2. Classification of sports by starting and specialisation ages (sports with n>20).

The analysis clearly shows that sports differ highly in terms of starting and specialisation ages. Additionally, even within the same sport, we can see considerable variation between athletes, as shown in Fig. 3 and Fig. 4. The highest variations in starting ages can be seen in archery, with variations in starting ages ranging from 0 to 54. The lowest variations are seen in artistic gymnastics, tennis, and synchronised swimming (Fig. 3). In terms of specialisation ages, we see many individual differences in archery, shooting, and equestrian. The lowest variations in specialisation ages can be seen in rhythmic gymnastics, weightlifting, and wrestling (Fig. 4).

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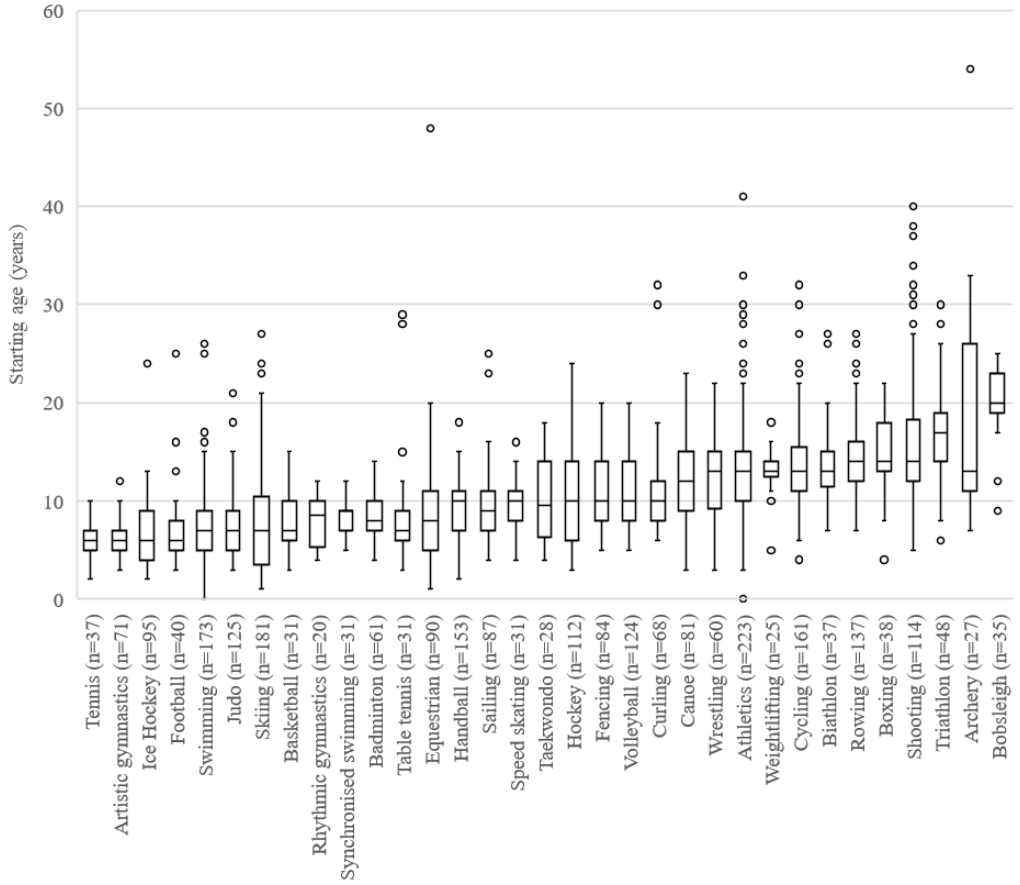

Fig. 3. Boxplot of ages at which athletes started with their sport (sports with n>20).

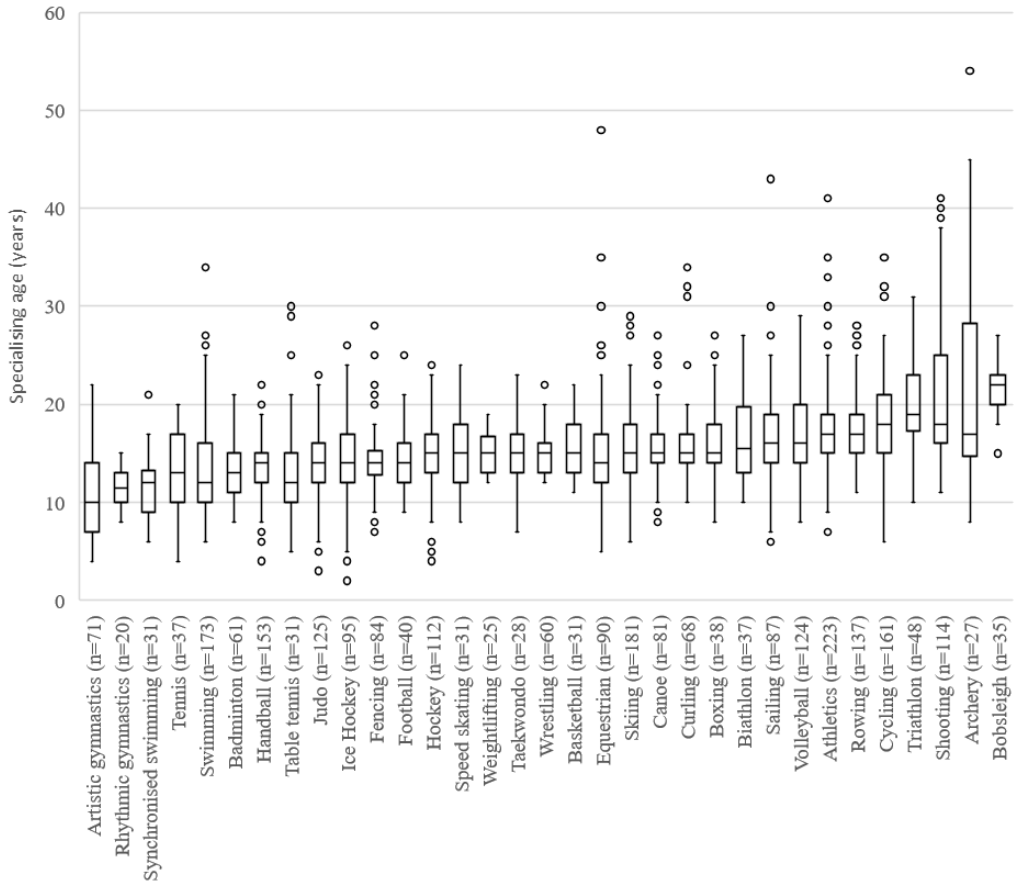

Fig. 4. Boxplot of ages at which athletes specialised in their sport (sports with n>20).

It is possible that differences between individuals can, in part, be explained by gender differences. As shown in Table I, when looking at starting ages, we see that male athletes start significantly earlier than female athletes in cycling, fencing, football, rowing, and tennis. However, female athletes tend to start earlier than males in canoe and hockey. According to the specialisation ages, we see an earlier specialisation of men in wrestling. By contrast, in artistic gymnastics, basketball, shooting, and volleyball, we see significantly lower specialisation ages in females than in males.

TABLE I: SPORT-SPECIFIC GENDER DIFFERENCES IN STARTING AND SPECIALISATION AGES

Sport	Starting age			Specialisation age		
	Male athletes Mean ±SD (n)	Female athletes Mean ± SD (n)	Gender difference t-value (p-value)	Male athletes Mean ±SD (n)	Female athletes Mean ±SD (n)	Gender difference t-value (p-value)
Archery	18.2 ±13.0 (14)	16.6 ±8.5 (13)	0.4 (0.710)	21.1 ±11.4 (14)	21.3 ±10.6 (12)	0.0 (0.981)
Artistic gymnastics	6.3 ±1.6 (45)	6.1 ±1.7 (26)	0.5 (0.625)	11.6 ±4.2 (45)	9.2 ±3.4 (26)	2.5 (0.015) *
Athletics	13.5 ±5.0 (132)	12.3 ±4.7 (91)	1.8 (0.072)	17.8 ±4.3 (132)	16.9 ±4.4 (88)	1.5 (0.134)
Badminton	8.4 ±2.2 (30)	8.3 ±2.3 (31)	0.1 (0.893)	13.4 ±3.3 (29)	13.3 ±3.3 (30)	0.1 (0.957)
Baseball	(4)	(0)		(4)	(0)	
Basketball	8.0 ±2.8 (16)	7.9 ±3.5 (14)	0.1 (0.951)	16.4 ±3.1 (16)	14.2 ±2.3 (14)	2.2 (0.037) *
Biathlon	13.6 ±4.8 (22)	13.7 ±2.8 (15)	-0.1 (0.191)	17.2 ±5.4 (21)	15.4 ±3.00 (15)	1.3 (0.210)
Bobsleigh	20.3 ±2.7 (21)	20.0 ±4.0 (14)	0.3 (0.769)	21.7 ±2.5 (21)	21.9 ±3.1 (14)	-0.2 (0.841)
Boxing	14.4 ±3.5 (25)	15.2 ±3.3 (13)	-0.7 (0.487)	16.2 ±3.4 (25)	16.6 ±4.3 (13)	-0.4 (0.723)
Canoe	13.0 ±3.8 (46)	11.1 ±3.4 (34)	2.3 (0.025) *	16.1 ±3.5 (45)	15.0 ±3.0 (34)	1.4 (0.171)
Curling	10.8 ±4.7 (36)	11.1 ±4.1 (32)	-0.2 (0.809)	15.8 ±4.0 (36)	16.6 ±5.4 (32)	-0.7 (0.483)
Cycling	12.1 ±3.3 (96)	15.2 ±5.6 (64)	-4.0 (<0.001) ***	17.2 ±3.7 (96)	18.8 ±5.5 (64)	-2.0 (0.047)
Diving	(2)	(1)		(2)	(1)	
Equestrian	8.8 ±7.7 (34)	8.8 ±4.4 (55)	0.0 (0.963)	15.9 ±7.8 (34)	15.3 ±5.8 (55)	0.4 (0.689)
Fencing	10.3 ±3.4 (52)	11.9 ±3.2 (32)	-2.1 (0.036) *	14.1 ±3.6 (51)	14.3 ±3.2 (31)	-0.2 (0.880)
Figure skating	5.8 ±1.8 (6)	5.3 ±1.2 (9)	0.6 (0.535)	11.6 ±2.7 (5)	8.4 ±2.8 (9)	2.1 (0.063)
Football	5.3 ±1.7 (18)	8.3 ±4.6 (22)	-2.6 (0.014) *	14.3 ±2.9 (18)	14.7 ±3.6 (22)	-0.4 (0.672)
Golf	(0)	(2)		(0)	(2)	
Handball	9.6 ±2.9 (97)	9.0 ±3.3 (56)	1.1 (0.282)	13.4 ±3.2 (96)	14.0 ±1.9 (56)	-1.4 (0.152)
Hockey	11.1 ±5.0 (68)	9.0 ±4.6 (44)	2.3 (0.024) *	14.6 ±4.0 (66)	14.8 ±3.6 (42)	-0.4 (0.704)
Ice Hockey	6.9 ±3.5 (72)	6.7 ±2.7 (23)	0.2 (0.825)	14.5 ±4.2 (70)	12.8 ±4.3 (23)	1.7 (0.093)
Judo	7.6 ±3.7 (64)	7.8 ±2.5 (61)	-0.3 (0.754)	13.4 ±3.6 (62)	14.4 ±3.4 (61)	-1.5 (0.143)
Kayak	(10)	(1)		(10)	(1)	
Modern pentathlon	15.3 ±3.0 (12)	16.0 ±2.7 (4)	-0.4 (6.552)	16.0 ±2.7 (12)	19.8 ±7.3 (4)	-1.0 (0.382)
Mountain bike	(0)	(1)		(0)	(1)	
Rowing	13.9 ±3.1 (97)	15.7 ±4.4 (40)	-2.4 (0.022) *	17.1 ±2.8 (96)	18.6 ±4.9 (40)	-1.8 (0.074)
Rugby	(3)	(5)		(3)	(5)	
Rhythmic gymnastics	(0)	(20)		(0)	(20)	
Sailing	10.0 ±4.4 (51)	9.0 ±2.6 (36)	1.3 (0.201)	16.6 ±4.3 (51)	16.9 ±6.5 (36)	-0.3 (0.760)
Shooting	16.3 ±7.1 (66)	16.0 ±6.5 (48)	0.3 (0.800)	22.2 ±8.0 (66)	19.5 ±6.3 (48)	2.0 (0.047) *
Skiing	8.0 ±4.3 (109)	7.9 ±5.8 (72)	0.1 (0.921)	15.5 ±4.2 (109)	15.8 ±4.2 (73)	-0.6 (0.555)
Softball	(0)	(14)		(0)	(14)	
Speed skating	9.1 ±2.5 (17)	10.4 ±2.7 (14)	-1.4 (0.179)	15.0 ±4.5 (17)	14.7 ±3.2 (14)	0.2 (0.842)
Swimming	7.2 ±4.2 (99)	7.4 ±3.2 (74)	-0.3 (0.791)	13.5 ±4.5 (99)	12.9 ±4.3 (72)	0.9 (0.376)
Synchronised swimming	(0)	(31)		(0)	(31)	
Table tennis	7.5 ±2.8 (19)	10.7 ±8.6 (12)	-1.2 (0.242)	13.3 ±4.7 (19)	14.5 ±7.2 (12)	-0.6 (0.567)
Taekwondo	10.0 ±4.2 (17)	9.8 ±4.6 (11)	0.1 (0.942)	14.4 ±3.7 (17)	15.9 ±2.9 (11)	-1.1 (0.296)
Tennis	5.6 ±1.8 (23)	6.8 ±1.4 (14)	-2.2 (0.038) *	13.3 ±4.3 (23)	12.4 ±3.3 (14)	0.7 (0.517)
Trampoline	7.9 ±3.2 (9)	8.3 ±3.3 (6)	-0.3 (0.797)	13.0 ±3.6 (9)	13.3 ±2.9 (6)	-0.2 (0.855)
Triathlon	16.3 ±4.1 (25)	18.1 ±6.0 (23)	-1.2 (0.222)	19.3 ±3.3 (25)	20.9 ±5.5 (23)	-1.2 (0.251)
Volleyball	11.4 ±4.4 (63)	10.5 ±3.2 (60)	1.3 (0.196)	17.9 ±4.3 (63)	16.1 ±3.6 (60)	0.1 (0.012)*
Water polo	11.7 ±2.0 (9)	9.8 ±2.2 (5)	1.6 (0.130)	14.2 ±5.3 (9)	13.8 ±1.6 (5)	0.2 (0.867)
Weightlifting	13.3 ±0.8 (11)	12.6 ±2.9 (12)	0.8 (0.448)	2.0 ±0.6 (11)	14.8 ±2.0 (11)	0.1 (0.916)
Wrestling	12.3 ±3.4 (43)	12.1 ±6.2 (17)	0.1 (0.908)	14.7 ±1.9 (43)	16.8 ±2.5 (16)	-3.3 (0.001)**

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

IV. DISCUSSION AND CONCLUSION

This paper aimed to provide insight into the differences in the starting and specialisation ages of world-class athletes in various Olympic sports. The data showed that, on average, the sample of athletes started

with their elite sport at the age of 10.6 years and decided to specialise in that sport at approximately 15.6 years of age. This finding means that in this sample, on average, athletes practised their sport for 4.9 years before they focused exclusively on it. Our results are consistent with the conclusion of Côté *et al.* (2007) and Vaeyens *et al.* (2009) that all international athletes need to start specialising at some point.

Our study is an addition to the study of Güllich (2007) cited in Vaeyens *et al.* (2009), who investigated the starting ages of 4,455 Olympians. Whereas we see some differences in our results, both studies support the main conclusion that there are major differences between sports in terms of starting ages. In both samples of world-class athletes, an early starting age, before the age of six, was not needed to reach their current level. Barth *et al.* (2022) advanced the field by summarising results on the importance of both the starting and specialisation ages to achieve later success. They compared lower-performing athletes with higher-performing athletes. The findings showed that an early starting and specialisation age led to juvenile success. On the other hand, a later start and later specialisation age were the hallmarks of higher-performing senior athletes. This study conducted no sport-specific analysis; rather, it compared five analytical categories of sports (Emrich *et al.*, 2001): objectively measured sports (e.g., time, weight, and distance), artistic composition sports, combat sports, game sports, and other sports. Their findings were consistent across these analytical categories of sports. However, our results add data at a sport-specific level and show large differences in sport-specific starting and specialisation ages, as well as between sports in the same analytical category (e.g., tennis and volleyball in-game sports). Future research should, therefore, analyse the influence of the starting and specialisation ages on success in each sport.

This study made a classification of most Olympic sports based on the age guidelines for starting and specialisation in elite sports in the DMSP (Côté *et al.*, 2007). The 33 Olympic sports investigated can be classified into five categories: (I) intermediate start and early specialisation, (II) intermediate start and intermediate specialisation, (III) intermediate start and late specialisation, (IV) late start and intermediate specialisation, and (V) late start and late specialisation. The five categories have diverse characteristics, which, therefore, point to the need for adaptations to the general talent development models.

In our world-class international athlete sample, early specialisation was only seen in artistic gymnastics, rhythmic gymnastics, and synchronised swimming. As stated in previous research, these sports are characterised by having an early peak performance age, which happens before physical maturation, requiring a specific physique, and which are individual sports (Balyi, 2001; Deakin & Cobley, 2003; DiSanti & Erickson, 2019; Law *et al.*, 2007; Mattson & Richards, 2010; Starkes *et al*., 2014). These sports characteristics show the necessity for an early start and early specialisation to obtain later international success. The DMSP presents the early specialisation pathway for these specific sports (Côté *et al.*, 2007). Whereas in our sample, early specialisation was apparent in just three sports, generally, it is common to see children specialising at very young ages. This phenomenon was noted in the ancient athletics contests in Greece and is still present in contemporary sports (Torres, 2015). However, in many sports, it could be preferable to delay early specialisation. Teetzel (2010) stated that we could try to decrease an early start and early intense deliberate practice in a single sport by diminishing the importance or attractiveness of juvenile peak performances. Therefore, in policy terms, it might be helpful to introduce minimum age limits in major events to protect the health and wellbeing of young athletes.

In the second category of sports, 15 of the 33 sports had an intermediate starting and specialisation age, which indicates that the sampling pathway of the DMSP (Côté *et al*., 2007) can lead to international standard performances. According to Côté *et al.* (2007), in the sampling years, the development of an athlete can be assured by high volumes of deliberate play and by participation in several sports. Only after the age of 12 should the volumes of deliberate practice increase so that an athlete can specialise in one sport.

The first two categories of sports, as described above, represent both proposed pathways in the DMSP, the early specialisation pathway in category I and the sampling pathway in category II. In all other categories, the DMSP model needs some modifications. Our third category consists of sports with an intermediate starting age and a late specialisation age, such as curling, sailing, and volleyball. These sports have a long sampling period. During the sampling period, it can be assumed that athletes practise their sport at a more recreational level, often in the context of a sports club, with other sporting activities on the side. Specialisation in their main sport occurs mostly after talent identification by a sports club or a national governing body of sport. An earlier study on the organisational perspective of talent development programmes shows that most athletes practised their sport for more than six years before they received support from their national governing body (De Bosscher & De Rycke, 2017). This support generally occurred at a relatively late age: club support at a mean age of 15.6 years and national governing body support at a mean age of 17.0 years. More academic research is required that focuses on this diversification phase and identifies how it needs to be organised. A gap in our knowledge is how many sports and which combination of sports can be beneficial to enable future success.

In the fourth category of sports, those with a late start but an intermediate specialisation age, the sampling period is very short. Our results show that in canoe, wrestling, and weightlifting, the world-class athletes did not have an early start. Traditionally, it is assumed that an early start in sports leads to a greater chance

of later sporting success because it is known that most fundamental movement skills are developed in childhood (Lubans *et al*., 2010). However, as already shown in the international sample of Güllich *et al.* (2007), to reach a world-class level of success, an early start is not a prerequisite. It can be suggested that in these late-starting sports, there is a transfer of skills from earlier sports. Research has shown that many skills can be transferable across sports, such as movement skills, perceptual skills, conceptual skills, and physical conditioning (Schmidt & Wrisberg, 2008). Future academic research should explore the possibilities for talent transfer in late-starting sports and investigate whether the preparation time before the actual start with the main sport has an influence on the later level of success.

Our final category, which includes sports with both a late start and a late specialisation, shows great variability in ages. Therefore, the diversification period is also extremely variable in this category. Bobsleigh, triathlon, archery, and shooting have very late starting and specialisation ages. As in the previous category, it is suggested that there is a transfer of skills from earlier sports to the late-starting sport, e.g. from sprinting to bobsleighing (Collins *et al.*, 2014). The developmental model for these sports should focus not only on the main sport but should also consider the preparation period.

This study has some limitations. First, early specialisation was not recorded in all its aspects, as the intensity and frequency of participation were not included in the data analysis. Secondly, in this study, only world-class athletes were included, so only the highest levels of achievement were represented. Therefore, it was not possible to differentiate the impact of starting or specialisation on the level of success. Further research should investigate whether there is a difference between medal-winning athletes (top three), world-class athletes and/or national-class athletes. Thus, this study is a modest contribution to the academic literature. However, it provides valuable empirical data on starting and specialisation ages. The major strengths of this study were the nature of a large international sample with data for almost all Olympic sports and the opportunity to make intra-sport and inter-sport comparisons.

To conclude, this study adds to the existing research in the talent development field and has implications for national sporting organisations (NSOs) in a variety of sports. NSOs need to encourage the implementation of sport-specific developmental models with increased attention to the sport-specific starting age, sampling period, and specialisation age. NSOs, coaches, and other stakeholders should be cautious in generalising talent identification and talent development strategies across sports as it is shown that an individual's developmental pathway is influenced not only by the type of sport but also by other contextual elements such as gender. It should be noted that there will always be individual differences between athletes in every sport. Future research should provide information on the impact of the sport-specific starting and specialisation age on the success of the athletes, on the sampling period, and on the skill transfer between sports.

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CONFLICT OF INTEREST

The authors declare that they have no known conflicts of interest concerning this research.

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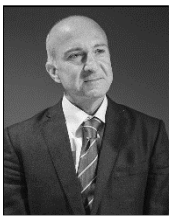

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