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ORIGINAL ARTICLE

Considering long-term sustainability in the development of world class success

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Abstract
The developmental practice patterns leading to the highest levels of success remain a subject of debate. The present study purposes to extend the body of empirical research by analysing athletic biographies from a large sample of German national squad athletes across all Olympic sports ($n = 1558$; 57% male, 43% female). In a combined retrospective and longitudinal study utilising postal questionnaires, we evaluated the age at onset, volume, domain-specificity, variability in training and competition and success attained at different ages. Developmental practice patterns leading to rapid adolescent success and long-term senior success were inconsistent, and in some aspects contradictory. An early start-age for training and competition, early specialisation, high-intensity specific practice in the respective domain sport and little or no involvement in other sports (OS) favoured early adolescent success. Juvenile success, however, did not contribute to individual differences in success achieved at a senior age ($-0.09 < r_s < 0.03$). Senior world class performers differed from national class athletes in a later age for onset of training and competition in their domain sport, later specialisation (14.4 vs. 12.1 years), more involvement in OS (training 66% vs. 51%; competitions 53% vs. 39%), but not in practice volume in their domain sport at any age. Findings were confirmed with longitudinal testing and were widely consistent across types of sports. These findings are interpreted relative to correspondence to deliberate practice and DMSP frameworks while drawing on the concept of long-term sustainability.

Keywords: *Expertise, training, early specialisation, variability, sustainability, longitudinal study*

Introduction

It is an accepted premise that outstanding athletes are successful because of the type and volume of their training. The developmental practice patterns leading to exceptional success, however, are an issue of debate in the literature. The volume, specialisation and variability of training during different periods of the athletic career are controversial. The notions of 1. early specialisation with reinforced intensity and expansion of domain-specific practice, and 2. diversified involvements with later specialisation have crystallised in the frameworks of Deliberate Practice (DP) (Ericsson, Krampe, & Tesch-Römer, 1993) and Diversification (DV) (Côté, Baker, & Abernethy, 2007).

Ericsson et al. proposed that attained performance is monotonically related to the performed volume of domain-specific DP. The authors described performance development as an input–output relationship, with the time spent on DP perceived as a critical input resource. They concluded that an early start of specialised practice was a prerequisite for maximisation of DP. Ericsson et al. further postulated that an early lead in performance would remain through all ages, which was augmented by access to the best coaches and training environments (p. 368, 387, 388).

Alternatively, many athletes participate in multiple sports during childhood and youth ages. In their Developmental Model of Sport Participation (DMSP), Côté et al. (2007) distinguished early diversification with late specialisation as an alternative path

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leading to athletic expertise. Some studies have reported the time successful athletes spent in their domain sport (DS) was negatively correlated with time spent in other sports (OS) (Baker, Côté, & Abernethy, 2003; Oldenziel, Gagné, & Gulbin, 2004), suggesting some functional role of participation in various sports. The DV approach suggests that participating in diverse sports during childhood promotes long-term athletic development based on positive motivational outcomes, reduced risks of motivational weariness and overuse injury and a broad repertoire of transferable motor skills (see Côté, Lidor, & Hackfort, 2009, for a review). Côté et al. (2007) proposed transfer of skills, and energetic capacities such as strength and endurance particularly across related sports sharing common conceptual, perceptual, movement and/or physical conditioning elements (Schmidt & Wrisberg, 2000).

Multiple investigations have documented practice histories including domain-specific and outside-domain practice volume of athletes across manifold ages and levels of success (Table I). Results from these earlier investigations are, however, inconsistent. For example, practice volume in either of DS and OS correlated positively with success in some studies but not in others. Furthermore, among top senior-age athletes, a consistent effect of domain-specific practice volume on the distinction between world class (WC) and national class (NC) performers could not be demonstrated reliably to date. Alternatively,

Table I. Studies comparing more and less successful athletes at different ages and success levels relative to the amount of domain-specific and outside-domain activity.

Studies	Sports	Domain-specific activity	Outside-domain activity
Sub-adult athletes			
World class vs. national class			
Law, Côté and Ericsson (2007)	Rhythmic gymnastic	+	–
National class vs. regional class			
Ford, Ward, Hodges et al. (2009)[3]	Soccer	o	o
Weissensteiner et al. (2008)[3,5]	Cricket	+	+
National class vs. below regional class			
Butcher, Lindner and Johns (2002)	Various	+	+
Ford et al. (2009)[3]	Soccer	+	o
Hodge and Deakin (1998)	Karate	o	
Ward, Hodges, Williams and Starkes (2004)[3,5]	Soccer	+	–
Adult athletes			
World class vs. national class			
Carlson (1990)[1]	Tennis	o[a]	+
McConnell, Hill, Forster and Moore (2002)[1]	Various	o	o
Johnson (2006)[2]	Swimming	o	+
Ronbeck et al. (2009)	Long-distance skiing	o	+
Van Rossum (2000)	Field hockey	–	
World class vs. regional class			
Baker, Côté and Abernethy (2003)[3]	Team ball sports	+[b]	o
Duffy et al. (2004)[3]	Dart	+	
Ronbeck et al. (2009)	Long-distance skiing	o	+
National class vs. regional class			
Berry et al. (2008)[3,5]	Australian football	o	+[d]
Memmert et al. (2010)[1,4]	Team ball sports	o	o
Ronbeck et al. (2009)	Long-distance skiing	o	o
Weissensteiner et al. (2008)[3,5]	Cricket	+	o
National class vs. below regional class			
Baker, Côté and Deakin (2006)	Triathlon	+[b]	+
Helsen, Starkes and Hodges (1998)	Soccer, field hockey	+[b]	
Hodges and Starkes (1996)	Wrestling	+[b]	
Hodges, Kerr, Starkes, Weir and Nananidou (2004)	Triathlon, swimming	+[c]	

+, positive correlation with success, o = indifferent, – = negative correlation with success.

Notes: All studies documented volume of activity in the respective DS. Some studies differentiated settings (organised training sessions, physical leisure play) and types of activities in the DS (practice, play, competition): [1]DS practice, play; [2]DS practice, competitions; [3]DS practice, play, competitions. Some of the studies investigating activities in OS differentiated settings and types of these activities: [4]OS practice, play; [5]OS practice, play, competitions.

[a]Less domain-specific practice until age 14 years, more after age 15 years. [b] Difference between success groups only in late adolescence or adulthood. [c] Within swimming, differences in practice volume only among competitors over longer distances, not in sprint events. [d] Comparison of players with higher and lower perceptual and decision-making skills among first league teams; positive effect only for invasion type games, not other types.

analyses in tennis, swimming and Nordic skiing revealed that WC athletes differed from NC in more participation in OS during childhood and adolescence (Carlson, 1990; Johnson, 2006; Ronbeck, Dunnagan, & Stewart, 2009; Table I).

Most of the earlier studies included youth athletes or senior athletes below international top level. Comparative studies examining developmental practice patterns of the most accomplished performers, i.e. senior WC, are scarce and typically based on small sample sizes. In addition, studies comparing the relationship between practice biographies and attained success across different types of sports are lacking. There is uncertainty about the scope of earlier findings with regard to 1. practice histories that promote international senior success, 2. potential differences across types of sports and 3. combinations of related or unrelated sports athletes may have practiced.

The purpose of this study was to extend the body of empirical research by examining athletic biographies in a large sample of German WC and NC athletes across all Olympic sports. We compared more and relatively less successful athletes regarding the age-related volume, domain-specificity and sports-spanning variability of training and competition. The early specialisation approach and the DP framework predict that athletes attaining higher levels of success would be differentiated from less successful athletes as a consequence of an earlier onset and higher aggregated volume of domain-specific practice. Alternatively, the DV theory predicts that involvement in multiple sports at a young age with a subsequent specialisation would contribute to later athletic success.

Methods

We reanalysed an existing data-set that had been collected for the purpose of evaluating athlete support programmes.

Study design

The investigation proceeded in three distinct but logically progressive partial studies.

Study 1. Athletic biographies of athletes with higher and lower success during adolescence and at a senior age were compared. The questions included:

- In which characteristics of the training and competition biography did more and less successful performers differ? What did they have in common? To what extent did the more successful athletes vary among each other?
- To what extent are athletic biographies leading to early adolescent success and to long-term senior success consistent or inconsistent?

Study 2. The findings were tested in a longitudinal design over three years from 1999 (t_1) to 2002 (t_2). The main question was:

- To what extent does success development from t_1 to t_2, and resultant success at t_2 vary with characteristics of practice and competition performed in the time periods prior to t_1, and from t_1 to t_2?

Study 3. We addressed the scope of the findings by comparing different types of sports and combinations of practiced sports. The main questions were:

- To what extent is the relationship between attributes of the practice biography and attained success consistent or inconsistent across different types of sports?
- To what extent does the frequency distribution of OS practiced by squad athletes correspond to or deviate from the frequency distribution of sports in total German youth participation?
- Can particularly successful combinations of related types of practiced sports be revealed?

Participants

The German Sports Association (DSB) provided the postal addresses of all squad members in all Olympic sports in the fall of 1999 (t_1) and 2002 (t_2). We submitted questionnaires via postal mailings, including a cover letter informing the athletes of the purpose and content of the study. Potential participants were instructed that their response was voluntary, all responses would remain anonymous, and the use of the data was exclusively for scientific purposes. This study was approved by the data protection supervisor of the DSB and received ethical approval from the German Federal Institute of Sport Science.

The procedure for drawing the samples in partial studies 1–3 is illustrated in Figure 1. We submitted questionnaires to a random sample at t_1 ($n = 2000$). A total of 776 athletes responded. The sample obtained at t_2 consisted of all respondents from t_1 as well as an additional 1232 athletes selected at random. We received responses from a total of 1034 athletes at t_2 including 244 respondents from t_1. Thus, data collection resulted in a total of 3232 addressees and 1566 participants (response rate,

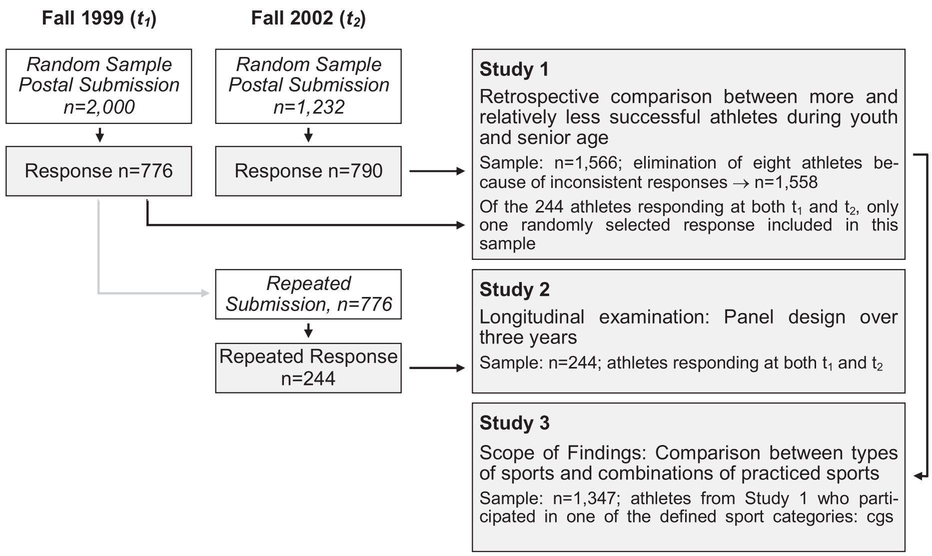

Figure 1. Study design and procedure for drawing the samples in partial studies 1–3.

49%). Eight cases were eliminated because of inconsistent responses.

Respondents at t_1 and t_2 did not differ significantly in gender, age, sport type (see below), squad level and region of residence (East or West Germany) which enabled pooling of all participants for a single sample ($n = 1558$) for study 1 (of the 244 athletes responding at both t_1 and t_2, only one of the randomly selected responses was included in this sample).

The sample was representative of all German squad members in Olympic sports including gender (57% male, 43% female), sport category, squad level and region of residence. At the time of data collection, 55% were categorised as junior level according to the international competition system in their respective DS (age 17.1 ± 1.6 years; M ± SD). For example, female swimming ≤ 16, tennis ≤ 18, judo ≤ 19 years, etc. This left 45% of the sample within the senior age level (24.4 ± 4.8 years). The sample included 387 athletes who attained top ten places at Olympic Games and/or senior world championships (WC) (including 240 medallists, 119 champions), and 213 athletes with top ten ranks at national senior championships (including 164 medallists, 50 champions) but no international top ten achievement (NC). The WC and NC performers did not differ significantly in the distribution of gender or sport categories ($p > 0.05$).

Among the 244 athletes who responded at both testing intervals, 123 were juniors at t_1 and 119 were seniors (missing age data in two cases). The longitudinal analysis (study 2) was confined to the senior cohort (24.4 ± 4.6 years at t_1) because only nine of the juniors were still adolescent at t_2.

Comparison across different types of sports (study 3) was based on 1347 respondents from study 1 who participated in one of the defined sport categories (see below).

Measurement of the development of training, competition and success

The survey included questions concerning the volume, continuity and domain-specificity of the athletes' training and competition involvement, and their success development. The following variables were recorded:

- The DS and OS potentially practiced for ≤ 1 year or longer
- Age for start of training and competition in the DS and each OS, cessation of participation in OS, and complete specialisation exclusively in the DS
- Number and duration of training sessions (DS, OS) within the age categories of ≤ 10, 11–14, 15–18, 19–21, 22–25 and 26 + years
- Periods of training reduction or interruption
- Highest success attained within each age category and in the last 12 months; success data were recorded in a three-digit code with the first digit representing the level of the highest championship reached (values 1–5: world, Europe [only for juniors], national, regional, below), and the second and third digit representing the attained place (values 1–99).

The athletes' reports referred to involvement in sport clubs/federations only, but not scholastic physical education or physical leisure play.

Table II. Analytical categories of sports (from Emrich et al., 2001) and Olympic domain sports of athletes in this study.

Category	Definition
Cgs-sports	Performance is measured in centimetres, grams or seconds (cgs). The task is to minimise time or to maximise distance or weight. Olympic sports: Alpine skiing, athletics, biathlon, bobsledding, cycling, ice speed skating, kayak/canoe, luge, long-distance skiing, rowing, skeleton, swimming, triathlon, weightlifting.
Artistic composition sports	A sequence of skills is composed and the execution is rated by judges based on the skills' difficulty and the accuracy and aesthetic expression of their execution. Performance is defined as the result of the judges' rating. Olympic sports: artistic gymnastics, figure skating, platform diving, rhythmic gymnastics, synchronised swimming, trampoline.
Martial arts sports	The task is to strike the opponent's body with a hand, foot, leg or equipment and/or to disturb the opponent's balance while overcoming the opponent's direct opposition. Performance is defined as the frequency and/or effect of the strikes and/or of disturbing the opponent's balance as rated by judges. Olympic sports: Boxing, fencing, judo, wrestling, taekwondo.
Game sports	The task is to place a ball (or puck, shuttle etc.) either in a field in a manner it cannot be returned accurately by the opponent (net games) or in a goal, basket, zone etc. (invasion games) or to place players in a zone (run and field games) while overcoming the opponent's direct opposition. Performance is defined as the frequency of these events. Olympic sports: Badminton, baseball, basketball, beach volleyball, curling, field hockey, handball, hockey, soccer, softball, table tennis, tennis, volleyball, water polo.
Others	Sports that fulfil none or various of these criteria. Olympic sports: Archery, equestrian, modern pentathlon, Nordic combination, sailing, shooting, ski jumping, snowboard, windsurfing.

Case-frequencies varied in some variables. Reports of achieved success or training volume within an age category referred only to athletes who had completed this age. Some variables were not applicable to all athletes, and there were missing values. Underlying case-frequencies were calculated for each variable.

Types of sports

These athletes consisted of squad members in 47 different Olympic sports (Table II). There were 313 different combinations of sports in which the athletes participated. Thus, comparison between types of sports, and combinations of practiced sports (study 3) required a categorisation. We elected to categorise sports analytically based on their competition rules. The rules define each sport and they structure the motor task in competition by defining the goal, permitted modes of acting and the criteria of valuation (Emrich, Pitsch, & Papathanassiou, 2001): Cgs sports, artistic composition sports, martial arts sports, game sports and others (Table II). The residual category of 'others' was excluded from study 3. This categorisation enabled exploration of the scope of findings across different types of sports including different types of predominant training activities, distinction between conceptually related and unrelated sports (Schmidt & Wrisberg, 2000) and, above all, provided mutually exclusive categories.

Statistical analyses

Analyses were performed using SPSS 19.0. We compared senior WC and NC athletes. Comparisons between success groups for adolescence were based on ≥ national top ten versus below at 14 years.

Descriptive data calculated for the sample included frequency distribution, mean value, standard deviation and Pearson's variability coefficient (V). Group differences were analysed using chi-square test (χ^2) and unpaired T-test. A non-parametric U-test was conducted for non-uniformly distributed data.

In the longitudinal study (study 2), ANOVA with a repeated factor of time (General Linear Model, GLM) was used to test effects of training and competition characteristics until t_1, and from t_1 to t_2, on success development. Between-subject factors were dichotomised by a median split, respectively. Effects of the characteristics of the sport biography until t_1, and from t_1 to t_2, on the resultant success at t_2 were examined by multiple linear regression analysis (MLR, backwards variable inclusion, exclusion criterion $p \geq 0.10$). The success data were converted into ranks within the sub-sample for these procedures to guarantee formal equidistance of the values (cf. Bortz, 2005), thus representing the relative success within the sample.

Iterations included the duration of involvement in training and competitions, discontinuities, training volume and success within age categories, and aggregated sessions until t_1, and from t_1 to t_2, in each case in the athlete's respective DS, OS, as well as the sum of both.

Interactions between success and sport category with regard to variables of the athletic history (study 3) were analysed with 2×4 ANOVA (two success levels x four sport categories).

Effect sizes are expressed as *phi coefficient* (φ) in χ^2 statistics, Cohen's *d* using pooled variance for differences in group means, *partial eta-squared* (η_p^2) in ANOVA, and *adjusted* R^2 (R^2_{adj}) in MLR. Effects were considered small, medium or large according to Cohen's guidelines (φ 0.1, 0.3, 0.5; *d* 0.2, 0.5, 0.8; η_p^2 0.01, 0.06, 0.14; R^2_{adj} 0.02, 0.25, 0.40). All statistical hypothesis testing was two-tailed. A value of $p < 0.05$ was considered statistically significant.

Results

Reliability

The panel design enabled the testing of the retest-reliability of the athletes' responses. The respondents' recall of age-related 'milestones' ($0.82 < r_{tt} < 1.00$), success levels ($0.90 < r_{tt} < 0.99$) and frequencies of training sessions ($0.80 < r_{tt} < 0.98$) within the different age categories was very reliable. The duration of the training sessions was not reported as consistently across all age categories ($0.45 < r_{tt} < 0.89$). No significant differences in the mean duration of a training session were revealed between more and less successful performers at any age. Consequently, training intensities were analysed based on the training session frequency.

In addition, 29 national junior squad rowers completed the questionnaire under our personal supervision during a training camp as part of a pilot study. Afterwards, they also provided their individual daily training diaries for this one-year season, which enabled comparison of the frequency of training sessions reported in the questionnaire with the daily logs. The reliability coefficients were $r = 0.88$ for session frequency and $r = 0.84$ for logged training time.

Study 1: Training and competition biographies of senior athletes

The senior WC athletes started training at 9.1 ± 3.7 and competing at 10.9 ± 3.8 years. They increased the mean frequency of annual training sessions from 100 ± 108 (≤ 10 years) to 350 ± 187 (15–18) and 487 ± 245 sessions *p.a.* (≥ 22 years). The mean duration of a training session progressed from 90 ± 30 minutes in childhood to 123 ± 41 in late adolescence, and 138 ± 46 minutes in adulthood. The training volume as well as juvenile success varied immensely among these senior high performers. For example, at age 14 years 4% of the WC athletes had attained top ten places at an international level, 31% at national, 23% at regional level and 42% below. At the age of 18 years, 49% had attained international top ten achievements, 32% at national, 8% at regional level and 12% below. Within 16 single sports with $n \geq 10$ WC performers, Pearson's V ranged from 22% to 56% for the age of training start, $67\% < V < 365\%$ for performed training sessions at ≤ 10 years, $45\% < V < 131\%$ at 11–14 years, and $28\% < V < 126\%$ for sessions at 15–18 years.

Success levels attained within adjacent juvenile age categories correlated moderately (≤ 10 and 11–14 years $r_s = 0.47$, 11–14 and 15–18 years $r_s = 0.33$, $p < 0.01$). Juvenile success levels, however, did not correlate significantly with achieved senior success (≤ 10 years $r_s = -0.07$, 11–14 years $r_s = -0.09$, 15–18 years $r_s = 0.03$; $p > 0.05$, respectively).

Each of the developmental 'milestones' for the onset of training (11.4 ± 4.7 vs. 10.1 ± 4.3 years, $T = 3.45$, $d = 0.29$), competition (13.1 ± 4.3 vs. 12.0 ± 4.3 years, $T = 3.09$, $d = 0.26$) and complete specialisation in the respective DS (14.4 ± 6.6 vs. 12.1 ± 5.5 years, $Z = 4.17$, $d = 0.38$) occurred at significantly later ages among the WC compared to the NC senior athletes (all $p < 0.01$). Consequently, smaller proportions of WC than NC athletes participated in their respective DS already during childhood (training ≤ 10 years 46% vs. 63%, $\chi^2 = 15.14$, $\varphi = 0.16$; 11–14 years 79% vs. 89%, $\chi^2 = 10.70$, $\varphi = 0.14$; competition ≤ 10 years 29% vs. 42%, $\chi^2 = 9.03$, $\varphi = 0.13$; 11–14 years 67% vs. 78%, $\chi^2 = 7.75$, $\varphi = 0.12$; all $p < 0.01$).

There was no significant difference between the proportion of senior WC and NC competitors practicing OS for up to one year ($p > 0.05$), but they differed significantly in practice of OS over longer periods, with 66% of the WC and 51% of the NC training in OS ($\chi^2 = 12.40$, $\varphi = 0.15$), and 53% compared to 39% competing in OS over more than one year ($\chi^2 = 9.48$, $\varphi = 0.14$; $p < 0.01$, respectively). The proportion of WC athletes participating in OS was higher than within NC through all age periods, for example at ≤ 14 years 57% vs. 45% ($\chi^2 = 7.39$, $\varphi = 0.11$), 15–18 years 42% vs. 23% ($\chi^2 = 20.14$, $\varphi = 0.19$), and also at 19+ years 32% versus 17% ($\chi^2 = 16.10$, $\varphi = 0.17$; all $p < 0.01$). Forty-six per cent of the WC and 32% of NC performers had changed their main sport at least once during their career ($\chi^2 = 11.65$, $p < 0.01$, $\varphi = 0.14$). The proportion of performers with WC success was 56% among those who were involved in no OS, 67% among those with one OS, 69% with two OS and 76% with three or more OS ($\chi^2 = 15.50$, $p < 0.01$, $\varphi = 0.17$).

The success groups did not differ significantly in the age for introduction to OS (9.5 ± 5.4 and 8.6 ± 4.4 years, $p > 0.05$), but the duration of the participation was longer among WC athletes for both training (8.7 ± 6.4 vs. 6.9 ± 4.7 years, $T = 2.59$, $p < 0.05$, $d = 0.32$) and competition (7.6 ± 6.0 vs. 4.0 ± 4.0 years, $T = 5.36$, $p < 0.01$, $d = 0.71$). Neither the succession of training onset in OS and DS, nor

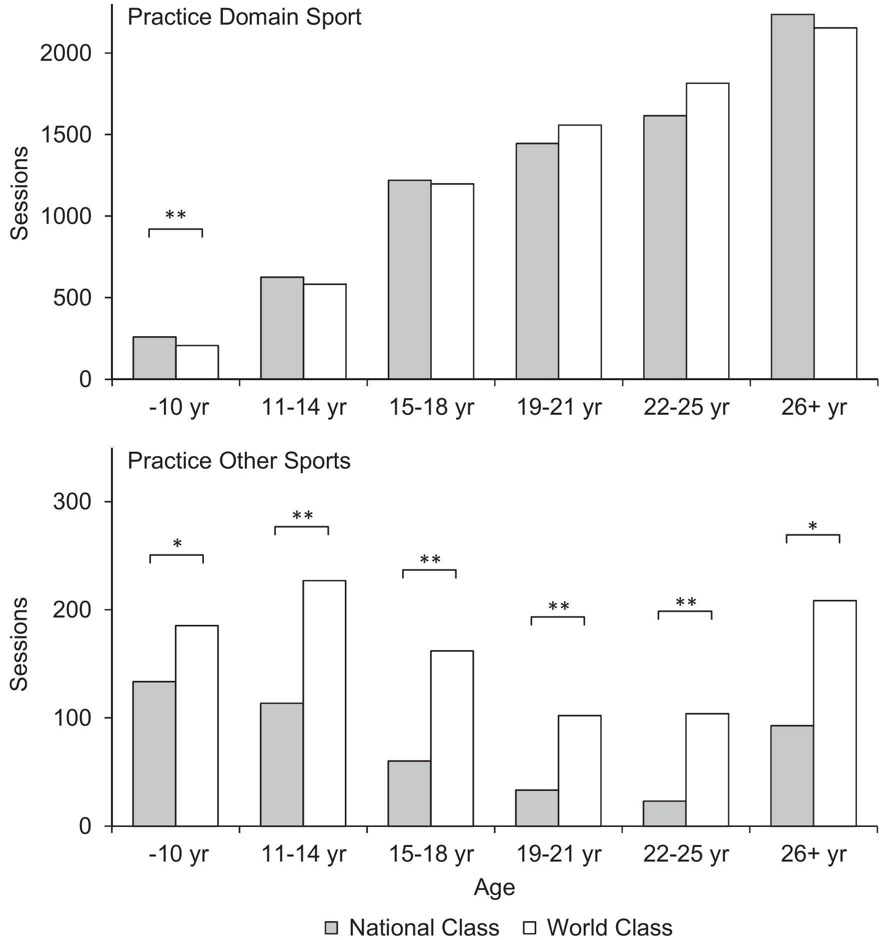

Figure 2. Frequency of performed training sessions in the athlete's respective domain sport (above) and in other sports (below) within defined age categories among senior world class (white columns) and national class (coloured columns) athletes. Columns represent mean values (standard deviations omitted for clarity). $^*p < 0.05$; $^{**}p < 0.01$. Group differences (*U*-Test) domain sport: ≤10 years $Z = 2.67$, $p < 0.01$, $d = 0.15$; all other age categories $p > 0.05$. Other sports: ≤10 years $Z = 2.08$, $p < 0.05$, $d = 0.13$; 11–14 years $Z = 3.65$, $p < 0.01$, $d = 0.35$; 15–18 years $Z = 3.98$, $p < 0.01$, $d = 0.38$; 19–21 years $Z = 3.32$, $p < 0.01$, $d = 0.33$; 22–25 years $Z = 3.28$, $p < 0.01$, $d = 0.36$; ≥26 years $Z = 1.98$, $p < 0.05$, $d = 0.24$. Note the different ordinate scales above and below.

the type of transition between practiced sports (overlap, seamless or with interruption) differed between WC and NC ($p > 0.05$).

No significant group differences between WC and NC athletes were identified for total training intensity (sum DS + OS) within any age category, or total training volume aggregated until any given age ($p > 0.05$). Figure 2 displays the training volumes performed within defined age categories in the athlete's respective DS and in OS. More and less successful senior athletes did not differ systematically in the number of training sessions performed in their DS at age 11 + years. Only the amount of discipline-specific training until age 10 years was slightly but significantly lower in the WC competitors. The WC athletes' training intensity in OS was significantly higher through childhood, adolescence and adulthood.

From an applied perspective it is of particular interest what typifies athletes who were already very successful during adolescence but did *not* subsequently reach international senior success. Out of 165 senior athletes who were medallists at junior world or European championships through age 18 years, 126 became senior WC performers and 39 did not. Group comparison revealed no significant difference in the training volume in their DS performed at any age ($p > 0.05$). The senior WC athletes had, however, started training in their DS later (10.5 ± 3.4 vs. 9.1 ± 2.8 years, $T = 2.22$, $d = 0.45$) and performed more training sessions in OS (≤10 years 181 ± 382 vs. 63 ± 199, $Z = 2.12$, $d = 0.39$; 11–14 years 187 ± 306 vs. 54 ± 149, $Z = 2.59$, $d = 0.55$; 15–18 years 65 ± 134 vs. 7 ± 37, $Z = 2.54$, $d = 0.59$; all $p < 0.05$).

Training and competitions of early high performers

The athletes with higher success at age 14 years had started training, competing and specialised exclu-

Table III. Developmental training and competition features of athletes with higher and lower success at age 14 years (≥national top ten vs. below).

	Success			
	≥National	Below		
Training in other sports			p	φ
≤10 years	35%	48%	**	0.12
11–14 years	34%	55%	**	0.22
Competition in other sports				
≤10 years	25%	31%	*	0.07
11–14 years	24%	42%	**	0.19
Age at 'milestones' in the domain sport (years)				
	M (SD)	M (SD)	p	d
Start training	8.5 (2.5)	11.5 (4.7)	**	0.80
Start competing	9.9 (2.4)	13.3 (4.7)	**	0.91
Complete specialisation	10.5 (4.3)	13.8 (5.8)	**	0.65
Number of training sessions				
In DS ≤ 10 years	394 (541)	189 (305)	**	0.47
In DS 11–14 years	924 (497)	477 (448)	**	0.94
In OS ≤10 years	120 (297)	185 (418)	**	0.18
In OS 11–14 years	100 (223)	237 (386)	**	0.43

Note: d, Cohen's d; *$p<0.05$, **$p<0.01$; DS, domain sport; OS, other sports; ≥ national success $373<n<501$, below $451<n<608$.

sively in their DS at younger age, aggregated more training sessions in their DS with less participation in OS (Table III).

Study 2: Longitudinal study over three years

Success at t_1 and t_2 correlated moderately ($r=0.58$, $p<0.01$). Success development was independent of gender and sport type ($p>0.05$).

None of the variables of the total performed practice (DS+OS), or duration, volume, continuity or progression of practice or competition in the DS performed until t_1, or from t_1 to t_2, contributed significantly (univariately or in multivariate interaction) to explaining success development from t_1 to t_2, or resultant success at t_2 (all $p>0.05$). Only the practice amount in OS exhibited a significant success-differentiating effect, with athletes who were involved in outside-domain sports before t_1 displaying a clear positive subsequent relative success progress over the next three years (Figure 3). Those that specialised exclusively in their DS were characterised by a relative decrease, while neither group differed in success at t_1. Similar effects were revealed for the duration of the involvement in training and in competitions in OS, the total number of performed training sessions in OS, their relative proportion within all performed training until t_1, and also between t_1 and t_2 ($8.62<F<28.22$; $p<0.01$; $0.09<\eta_p^2<0.22$).

The multiple regression analysis (MLR) revealed that, notwithstanding the appreciable success-homogeneity within this sample, attained success at t_1 together with the duration of participation in competitions in outside-domain sports until t_1 accounted for a considerable proportion of success variance at t_2:

$$R^2_{adj} = 0.43 (R = 0.67; R^2 = 0.44)$$
$$\text{Rank } t_2 = 29.77 + 0.63 \bullet a - 0.20 \bullet b(\text{E1})$$
$$a = \text{success(rank) at } t_1$$
$$b = \text{duration of competition involvement in OS until } t_1$$
Note : Lower rank values represent higher success.

Equivalent results were found for the duration of training in OS until t_1, aggregated training sessions in these sports until t_1, and between t_1 and t_2 and the proportion of OS within the total performed training until t_1 ($0.37<R^2_{adj}<0.43$). All iterations introdu-

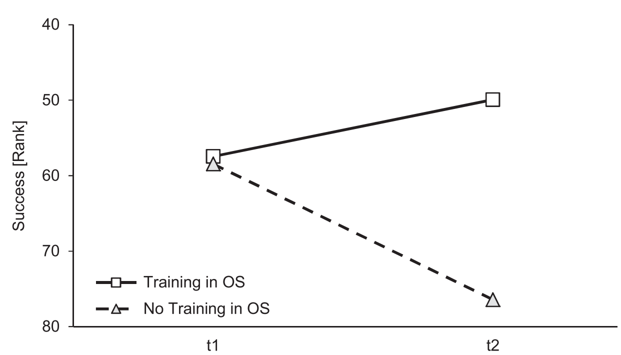

Figure 3. Relative success development (rank within the sample) over three years among senior athletes with (white squares) and without (grey triangles) involvement in other sports (OS) beyond their respective domain sport before t_1. Mean success values (rank; standard deviation omitted for clarity). Note: Lower rank values represent higher success, ordinate scale inverted. Success difference at t_1 $F=0.02$, $p>0.05$; at t_2 $F=16.94$, $p<0.01$. Interaction training in other sports • repeated measurement $F_{(1,\ 117)}=18.36$, $p<0.01$, $\eta_p^2=0.14$.

cing other independent variables failed to improve the prediction of success at t_2 ($p > 0.05$).

Study 3: The scope of the findings – comparison between types of sports

Tables IV and V display features of training and competition histories of athletes with higher and lower success at age 14 years and at senior age within different DS categories (DSCs).

Comparisons between all respondents from the respective DSCs revealed significant differences in most variables of their practice biographies ($3.94 < F < 108.08$, $p < 0.05$). Differences between relatively homogeneous sub-groups (*Scheffé* post hoc test) can be summarised as follows: The age for training and competition onset in the DS was composition < martial arts, game < cgs sports. Domain-specific training intensity until 14 years was composition > cgs, martial arts, game sports; at 15+ years composition, cgs > martial arts, game sports. Duration of involvement in OS was composition < cgs, martial arts, game sports. Interestingly, there were no differences between the DSCs regarding the practice intensity in OS in any age category ($p > 0.05$), except 11–14 years (composition < cgs, martial arts, game sports; $p < 0.05$).

Consistent across all DSCs, athletes with higher success at age 14 years were characterised by an earlier start of domain-specific training and competition, earlier complete specialisation and more intensive practice in their respective DS, and less involvement in OS (Table IV). Some effects varied in size across the DSCs, with ANOVA indicating larger effects in cgs-sports than in the other DSCs regarding age of training and competition onset in the DS, training intensity in the DS at 11–14 years, and in OS at ≤10 years ($3.42 < F < 6.66$, $p < 0.05$). However, the direction was consistent across all DSCs. In no category were any contrary findings revealed.

The analogous results for senior WC and NC performers are displayed in Table V. In none of the DSCs did the WC athletes display a significantly higher volume of domain-specific practice during childhood, adolescence or adulthood, with the exception of 19–21 years within artistic composition. Consistent across the DSCs, WC athletes differed primarily from NC competitors in later career 'milestones' in their respective DS and with more involvement in OS. Despite considerable differences in the athletes' training and competition biographies, no significant interaction between the DSC and senior success was found with regard to any variable of their practice history ($p > 0.05$). The exception was training intensity in the DS at ≤10 years, which indicated a significant negative effect within martial arts sports but not in the other DSCs ($F = 2.93$, $p < 0.05$).

Combinations of practiced sports

Defining each sport as a case, the frequencies of squad athletes' diverse OS, and the number of total youth in Germany involved in the different sports (DSB, 1991–1996), were correlated at $r = 0.88$.

Within the respondents involved in OS, 32% participated only in OS from their respective DSC, 48% only from other sport categories (OSC) and 20% both. The distribution did not differ significantly across age categories ($p > 0.05$).

No over-representation of any category of outside-domain sports practiced for ≤1 year was found within any DSC ($p > 0.05$). In contrast, participation >1 year exhibited a clear affinity pattern between related sports. Within each DSC, OS from the DSC were over-represented ($p < 0.05$; Table VI). However, no significant difference between athletes with higher and lower success, both at age 14 years and at senior age was found with regard to the involvement in OS only from their DSC, only from OSC or both ($p > 0.05$). In addition, further differentiation 1. within game sports based on conceptual relatedness (invasion, net/wall, field and run, target games), 2. within cgs-sports based on relatedness of physical conditioning (typical endurance sports like cycling, long-distance skiing, rowing, triathlon etc. versus others) and (3) individual/team sports confirmed in each case both the affinity pattern of participation ($p < 0.05$) and the failure to reveal any particularly successful combination of practiced types of sports ($p > 0.05$).

Discussion

This study evaluated training and competition biographies in a large sample of German squad athletes. Investigations included comparison between athletes with higher and lower success during adolescence and senior ages in retrospective design, longitudinal testing of the findings and the examination of the findings' scope across different types of sports. Analyses revealed that successful homogeneous groups of senior WC performers displayed heterogeneous juvenile training, competition and success histories. The study also indicated that juvenile success did not represent a reliable predictor for later success in senior elite sports. In addition, developmental practice patterns leading to early adolescent success and to long-term senior WC success were inconsistent and in some aspects contradictory. An early start of training and competition, early specialisation, intensive training in the DS with little or no involvement in OS mostly

Table IV. Characteristics of the training and competition history in the athlete's respective domain sport (DS) and in other sports (OS) among athletes with at least national success and below at age 14 years within defined categories of domain sports.

	Cgs sports				Artistic composition sports				Martial arts sports				Game sports			
	≥National class ($n=220$)	<National class ($n=337$)	p	φ	≥National class ($n=77$)	<National class ($n=20$)	p	φ	≥National class ($n=59$)	<National class ($n=51$)	p	φ	≥National class ($n=91$)	<National class ($n=139$)	p	φ
Training in OS	48%	68%	**	0.21	29%	35%	ns	0.06	42%	60%	x	0.18	54%	73%	**	0.20
Competitions in OS	39%	56%	**	0.17	25%	32%	ns	0.06	32%	42%	ns	0.10	38%	60%	**	0.21
Age of 'Milestones' (years)	M (SD)	M (SD)	p	d	M (SD)	M (SD)	p	d	M (SD)	M (SD)	p	d	*M (SD)*	*M (SD)*	p	d
Start training in DS	9.1 (2.4)	12.4 (4.3)	**	−0.95	7.1 (2.2)	8.1 (3.0)	ns	−0.38	7.7 (2.0)	9.1 (3.5)	x	−0.51	8.0 (2.5)	9.8 (4.9)	*	−0.48
Start competing in DS	10.3 (2.4)	13.7 (4.1)	**	−1.02	8.7 (1.9)	10.2 (3.9)	ns	−0.48	9.3 (2.2)	10.8 (3.5)	*	−0.51	9.7 (2.4)	12.0 (4.7)	**	−0.61
Complete specialisation in DS	11.1 (3.8)	13.9 (5.2)	**	−0.62	8.1 (3.5)	8.3 (2.9)	ns	−0.05	9.6 (4.4)	12.7 (6.0)	**	−0.60	10.8 (4.5)	13.8 (6.5)	**	−0.54
Duration until age 14 years (years)																
Training in OS	2.7 (3.6)	3.5 (3.6)	*	−0.20	1.9 (3.5)	2.8 (4.3)	ns	−0.23	1.9 (3.4)	2.8 (4.0)	ns	−0.23	3.4 (4.1)	4.0 (3.7)	ns	−0.14
Competitions in OS	1.9 (3.0)	2.7 (3.2)	*	−0.24	1.3 (2.8)	2.0 (3.4)	ns	−0.24	1.3 (2.7)	1.8 (3.3)	ns	−0.17	2.3 (3.4)	2.6 (3.1)	ns	−0.08
Number of training sessions																
In DS ≤10 years	277 (339)	105 (204)	**	0.62	830 (956)	789 (594)	ns	0.05	384 (290)	299 (299)	ns	0.29	342 (361)	313 (340)	ns	0.08
In DS 11–14 years	939 (472)	445 (462)	**	1.06	1293(558)	997 (587)	*	0.52	732 (339)	558 (291)	**	0.55	723 (304)	484 (347)	**	0.73
In OS ≤10 years	112 (279)	174 (364)	*	−0.17	120 (371)	476 (1023)	ns	−0.46	51 (201)	163 (403)	x	−0.35	159 (270)	196 (318)	ns	−0.12
In OS 11–14 years	104 (223)	272 (412)	**	−0.47	36 (123)	303 (657)	x	−0.57	93 (234)	107 (257)	ns	−0.05	116 (208)	224 (286)	**	−0.43

Notes: d – Cohen's d. Differences approaching significance marked because of smaller sub-sample sizes. x, $p<0.10$, *$p<0.05$, ** $p<0.01$, ns, not significant.

Table V. Characteristics of the training and competition history in the athlete's respective domain sport (DS) and in other sports (OS) among senior world class (WC) and national class (NC) athletes within defined categories of domain sports.

	Cgs sports				Artistic composition sports				Martial arts sports				Game sports			
	WC ($n=208$)	NC ($n=97$)	p	φ	WC ($n=20$)	NC ($n=24$)	p	φ	WC ($n=40$)	NC ($n=24$)	p	φ	WC ($n=73$)	NC ($n=44$)	p	φ
Training in OS	67%	52%	**	0.15	35%	29%	ns	0.06	65%	33%	*	0.34	78%	57%	*	0.23
Competitions in OS	55%	43%	x	0.11	32%	22%	ns	0.11	49%	21%	*	0.26	59%	39%	*	0.19
Age of 'Milestones' (years)	M (SD)	M (SD)	p	d	M (SD)	M (SD)	p	d	M (SD)	M (SD)	p	d	M (SD)	M (SD)	p	d
Start training in DS	12.3 (4.5)	11.0 (3.7)	*	0.31	7.8 (3.5)	6.8 (2.3)	ns	0.34	9.3 (2.9)	7.9 (2.9)	x	0.50	10.4 (4.7)	9.8 (3.9)	ns	0.13
Start competing in DS	13.8 (4.2)	12.6 (3.6)	*	0.31	9.7 (3.3)	8.5 (2.2)	ns	0.44	11.0 (2.8)	9.7 (3.0)	x	0.47	12.4 (4.5)	11.8 (4.1)	ns	0.17
First international championship	18.1 (3.2)	17.4 (2.7)	x	0.24	15.2 (2.3)	13.8 (2.6)	x	0.59	16.6 (2.8)	15.4 (4.2)	ns	0.34	17.6 (3.6)	17.6 (4.4)	ns	0.02
Complete specialisation in DS	14.3 (6.1)	13.0 (4.8)	x	0.23	8.7 (3.4)	8.8 (4.9)	ns	−0.04	12.0 (6.1)	9.9 (5.8)	x	0.48	15.4 (6.6)	11.3 (5.1)	**	0.70
Duration (years)																
Training in OS	4.7 (5.4)	3.1 (4.4)	*	0.32	2.4 (4.7)	2.2 (4.8)	ns	0.04	5.5 (7.6)	2.6 (6.1)	*	0.43	7.1 (7.1)	3.2 (4.2)	**	0.68
Competitions in OS	4.1 (5.3)	2.0 (3.4)	**	0.46	1.2 (2.6)	0.5 (1.5)	ns	0.30	3.4 (6.1)	1.3 (4.1)	*	0.43	4.7 (5.7)	1.7 (2.9)	**	0.68
Number of training sessions																
In DS ≤10 years	125 (238)	139 (216)	ns	−0.06	977 (880)	827 (544)	ns	0.20	233 (230)	429 (323)	**	−0.70	244 (311)	212 (283)	ns	0.11
In DS 11–14 years	577 (533)	571 (461)	ns	0.01	1209 (639)	1144 (435)	ns	0.12	635 (365)	572 (417)	ns	0.16	404 (310)	572 (472)	*	−0.42
In DS 15–18 years	1321 (805)	1333 (714)	ns	−0.02	1664 (760)	1347 (552)	ns	0.48	1089 (620)	1060 (484)	ns	0.05	791 (405)	1039 (545)	*	−0.52
In DS 19–21 years	1729 (904)	1597 (896)	ns	0.17	1963 (767)	1466 (547)	x	0.75	1349 (654)	1296 (626)	ns	0.08	1093 (626)	1288 (590)	ns	−0.32
In DS 22–25 years	2107 (872)	2118 (851)	ns	−0.01					1476 (711)	1378 (608)	ns	0.15	1297 (730)	1294 (548)	ns	0.00
In OS ≤10 years	175 (362)	123 (292)	ns	0.16	446 (985)	116 (413)	x	0.44	156 (320)	163 (504)	ns	−0.02	216 (319)	141 (276)	ns	0.25
In OS 11–14 years	262 (401)	113 (211)	**	0.46	179 (411)	107 (454)	ns	0.17	168 (329)	52 (133)	x	0.46	216 (294)	141 (246)	x	0.28
In OS 15–18 years	172 (381)	62 (174)	**	0.37	98 (263)	10 (45)	ns	0.47	139 (328)	21 (93)	x	0.49	159 (292)	68 (190)	*	0.37
In OS 19–21 years	95 (268)	29 (106)	*	0.32	37 (107)	3 (11)	ns	0.46	134 (308)	0 (0)	*	0.61	111 (269)	25 (77)	*	0.44
In OS 22–25 years	74 (215)	45 (81)	ns	0.27					108 (233)	0 (0)	*	0.66	94 (177)	49 (202)	ns	0.24

Notes: d, Cohen's d. Differences approaching significance marked because of smaller sub-sample sizes. x, $p<0.10$; *$p<0.05$; **$p<0.01$, ns, not significant. No data representation for composition sports at 22–25 years because of cell occupation of $n<10$.

Table VI. Frequency of types of practiced other sports among athletes from different categories of domain sports.

		Category of the domain sport				
		Cgs sports (%)	Composition sports (%)	Martial arts sports (%)	Game sports (%)	Total (%)
Category of other Sports	Cgs	52	38	38	33	45
	Composition	14	63	31	16	19
	Martial arts	12	6	23	4	10
	Games	48	38	62	74	56

Notes: Percentages within columns. Column sums exceed 100% because many athletes practiced other sports from various categories. Over-representation of other sports from the domain sport category: Cgs sports $\chi^2 = 9.54$, $p < 0.01$, $\varphi = 0.11$; composition sports $\chi^2 = 21.20$, $p < 0.01$, $\varphi = 0.16$; martial arts sports $\chi^2 = 5.97$, $p < 0.05$, $\varphi = 0.09$; game sports $\chi^2 = 16.43$, $p < 0.01$, $\varphi = 0.15$.

promoted rapid adolescent success. Alternatively, the domain-specific practice volume did not differentiate between senior WC and NC performers, with the former having mostly performed more training and competitions in OS through childhood, adolescence and adulthood, specialised later and displayed a rather decelerated training and competition development in their DS. Finally, an involvement in various related sports was over-represented compared to unrelated sports. However, no difference in the success-related effects could be revealed between involvement in related and unrelated sports. The frequency distribution of outside-domain sports the athletes participated in represented an accurate reflection of the distribution of sports in total youth participation.

These central findings were confirmed in longitudinal examination and they were widely consistent across different types of sports.

These results are consistent with previous work that included samples of athletes of comparable age and success ranges within single sports, relative to developmental practice patterns leading to early adolescent success (Ford, Ward, Hodges, & Williams, 2009; Law, Côté, & Ericsson, 2007; Ward et al., 2004; Weissensteiner, Abernethy, Farrow, & Müller, 2008), to the failure to reveal a distinction between senior WC and NC athletes based on the amount of domain-specific practice, and to the positive effect of sports-spanning practice variability in the development of senior WC success (Carlson, 1990; Johnson, 2006; Ronbeck et al., 2009; Van Rossum, 2000; Table I).

These observations do not question that voluminous domain-specific practice is critical to success. Strictly speaking, the present data exhibit correspondence with both the DP and the DV approach. Most athletes participated in diverse sports and also accumulated sizeable specific practice in their DS. However, we contend that the relation of attained success with the volume and domain-specificity of practice is neither linear nor monotonic across age and success levels. The scope of the success-differentiating power of the pattern of 'accumulating evermore of the same' inherent to the DP framework is apparently limited in predicting differences in success probability within the highest senior success ranges. Alternatively, the distinguishing effect of higher sports-spanning variability of training and competition is consistent with the Diversification approach. The present results provide an extension to the DMSP framework regarding 1. the inconsistency of developmental practice patterns leading to rapid adolescent success and long-term senior success, 2. the absence of data suggesting a superiority of an earlier specialisation for long-term attainment of senior WC success in any sports category, 3. the beneficial effect of sports-spanning variability of involvement not only during childhood but also during adolescence and adulthood and 4. the independence of the latter from the relatedness of sports practiced.

Theoretical implications – considering long-term sustainability

A theory of expertise in high-performance sports should help understand not only why many athletes may benefit from variable practice, but also why spending time in outside-domain practice resulted in even more long-term success than spending this time in domain-specific practice.

Outstanding performers must manage:

1. To end up in the sport discipline of their individual 'best fit'.
2. To balance the costs of their time consumption in sport successfully with time demands and interests outside of sport.
3. To improve individual performance while continuously balancing physiological, mechanical and psychological strain with their individual stress-tolerability.

We suggest the balance between availability, consumption, preservation, regeneration and new generation of individual resources represents a fruitful approach to understanding the developmental practice pattern most likely leading to senior WC success.

First, exploring various sports enhances the probability of functional matching between the athlete and the sport (principle of multiple sampling and functional matching). Matching may be related to diverse aspects such as the discipline's motor task, performance progress, demanded time investment, social relations, health and enjoyment. Less frequent WC athletes participating exclusively in their DS were thus individuals who either coincidentally 'hit' their sport of 'best fit' immediately, or possessed the potential to excel in various sports and their chosen sport was among these. These considerations are consistent with the findings that a larger proportion of the WC athletes reported to have changed their main sport during their career, and that the proportion of WC performers was highest when the athletes had experienced more sports.

The assignment of young athletes to their most appropriate sport can hardly be predicted reliably a priori (cf. 'talent identification'). The matching process rather proceeds based on long-term and authentic differential experience: long-term as only relatively long-lasting participation in diverse sports benefited later success; authentic as the involvement in various sports was mostly competition-related. This detail is important. In Germany, participating in formal competitions requires membership in the respective sport's organisation. This signifies that these athletes participated in diverse sports in different clubs or club divisions including peer athletes and specialist coaches of these sports. This explorative search process is narrowed based on experience: sports that were attempted and ceased within a short period of time (< 1 year) were more frequently conceptually unrelated to the athlete's respective DS, while sports involved in for longer were more frequently related to the DS.

Second, extensive practice is associated with both material and immaterial costs and risks. A failure to achieve balance is likely to lead to premature withdrawal. Any specific factor increasing attrition probability leads to an under-representation of individuals possessing this factor among senior elite athletes. Intensive specialised training at a young age together with early pursuit of competitive success have been noted to be associated with poorer subjective health perception, more injuries, reduced perception of enjoyment (Law et al., 2007), more frequent emotional and motivational weariness ('staleness', 'burnout'; cf. Gould, Udry, Tuffey, & Loehr, 1996; Matos & Winsley, 2007), and greater susceptibility to premature withdrawal (Fraser-Thomas, Côté, & Deakin, 2008; Wall & Côté, 2007). In contrast, participating in a variety of sports is presumed to foster positive affect and self-determined intrinsic motivation and thereby build a solid foundation of motivational 'starting capital' for subsequent prolonged investments (Csikszentmihalyi, Rathunde, & Whalen, 1993; Côté et al., 2009).

Non-specific stimuli are inferior to specific stimuli when inducing specific learning and adaptation effects (Foster, Hector, Welsh et al., 1995; Loy, Hoffmann, & Holland, 1995). Yet, they may still lead to some positive effects while circumventing the excessive accumulation of local stress and the predisposition to overuse injuries (Brenner, Small, Bernhardt et al., 2007; Helms, 1997).

Third, the search for solutions to motor tasks proceeds as a selection process based on memory contents and selection from within-subject fluctuation in practical skill executions (Davids, Glazier, Araújo, & Barlett, 2003). An amplified and closer-meshed 'recall-recognition network' (Wulf & Shea, 2002) may assist performance development in two ways. 1. High-performance in sport requires adaptive skills due to varying personal or environmental constraints, or purposely varying skills to hinder opposition. Hatano and Iganaki (1986) coined the term of 'adaptive experts', in contrast to 'routine experts' (c.f. Lewandowsky & Thomas, 2009; Sternberg & Frensch, 1992: expert's inflexibility). Adaptive experts not only perform procedural skills efficiently, but also understand the 'how' and 'why' of the skills. These individuals acquire 'conceptual knowledge' based on varied situations of problem-solving. 2. The exposure to a wider range of problem-solving situations provides the learner with a broad range of opportunities to discover the laws that organise the co-variation of action and consequence, encourages him or her to compare solutions and enables a more 'fine-grained' search process (Davids et al., 2003; Newell, Liu, & Mayer-Kress, 2001). Beyond a direct transfer of skills or energetic capacities between sports, the involvement in various sports presumably affords the varied learning stimuli that benefit the subsequent refinement of domain-specific skills.

Each of these effects – multiple sampling and functional matching, buffering of costs and risks and exposure to varied situations of problem-solving – may be independent of the relatedness of practiced sports. Relative to the transfer of perceptual and motor skills and energetic capacities acquired in one sport to practice in another sport (Abernethy, Baker, & Côté, 2005; Foster et al., 1995; Loy et al., 1995; Smeeton, Ward, & Williams, 2004), practice in most sports typically includes motor skill refinement, speed, agility, strength and endurance work to some extent. Transfer may thus be possible between numerous related or unrelated sports. While there is likely to be substantial individual variability, it is unknown whether an athlete's domain-specific performance development rather benefits from augmented practice of consistent motor dimensions in multiple related sports or from complementary acquisition of competencies that are under-represented in his/her DS practice. The enormous heterogeneity of coupled sports within this homogeneous sample presumably highlights the profound individuality of the functionality and availability of potential sports, and suggests beneficial effects of the principle of variability per se.

Methodological considerations

This study does have limitations. Type and volume of scholastic PE lessons and of deliberate play in leisure (cf. Côté et al., 2007) were not recorded. Volume and content of PE are highly standardised based on obligatory curricula throughout Germany. Deliberate play may be extensive during childhood. However, a consistent positive effect of deliberate play on senior success has not been demonstrated reliably to date. Most notably, there is no evidence to suggest that NC competitors would have experienced greater, or more diverse, deliberate play in OS while WC athletes would have performed less diverse deliberate play in OS and more and earlier deliberate play in their respective DS (cf. Baker et al., 2003; Berry, Abernethy, & Côté, 2008; Duffy, Baluch, & Ericsson, 2004; Ford et al., 2009; Memmert, Baker, & Bertsch, 2010; Ward et al., 2004; Weissensteiner et al., 2008).

The structure of the questionnaire afforded the opportunity to only report participation experiences in up to three OS. In addition, some athletes were still active in various sports at the time of response. Both constraints suggest a slight under-estimation of the amount of outside-domain practice in a number of athletes. However, since OS were over-represented in the WC performers, this bias advantages beta-errors rather than alpha-errors.

Finally, the limitations of group comparisons within a field of profound individuality need to be considered. All combinations of higher and lower practice volume, diversity and success were existent. Our analyses reflect 'only' majorities and minorities within this highly selective sample. The ensuing questions raised include, to what extent are successful careers composed by characteristics corresponding to DP and DV, and under which conditions and when are characteristics of DP and/or of DV beneficial?

Conclusion

Our data demonstrate that it is possible to reinforce rapid juvenile athletic development. Yet, a reinforced premature acceleration may lead to early exploitation of individual resources and to increased costs and risks. Alternatively, the investment pattern of most WC performers was more resource-preserving and risk-buffering and may in turn have assisted the generation of new resources for performance development.

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