©Journal of Sports Science and Medicine (2015) **14,** 634-642
http://www.jssm.org

Research article

The Relative Age Effect and Physical Fitness Characteristics in German Male Tennis Players

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Abstract
The aims of the study were to test: 1) whether the relative age effect (RAE) was prevalent in young (U12-U18) German male tennis players; 2) the potential influence of age and/or skill level on RAE and 3) whether maturity, anthropometric and fitness measures vary according to birth date distribution in elite youth tennis players. For the present study the following male populations were analysed: Overall German population (n = 3.216.811), all players affiliated to the German Tennis Federation (DTB) (n = 120.851), players with DTB official ranking (n = 7165), regional (n = 381) and national (n = 57) squads (11-17 years old), as well as the top 50 German senior players were analyzed. RAEs were more prevalent at higher competitive levels with more players born in the first quarter of the year compared with the reference population for ranked (29.6%), regional (38.1%) and national (42.1%) players. No systematic differences were found in any of the maturity, anthropometric and fitness characteristics of the regional squad players born across different quarters. RAEs are present in the DTB competitive system and it was more pronounced at higher competitive levels. Compared with early born, late born players who were selected into elite squads did not differ in maturation, anthropometric and fitness characteristics.

Key words: Birth distribution, racket sports, maturation, physical characteristics.

Introduction

The identification, selection, and development of talented tennis players at early ages can have significant social, professional, and financial implications for the players and their families (Abbott and Collins, 2004; Roetert and Ellenbecker, 2007; Vaeyens et al., 2008). A talented young tennis player can be considered as someone whose performance is better and/or increasing faster than his or her peers at training and competition (Elferink-Gemser et al., 2004). Typically, those players are surrounded by the social and material environmental conditions that increase the likelihood of them reaching the elite level (Hohmann, 2001) .

Like most competitive sports, youth tennis competition is divided into age categories based on chronological age as defined by a player's date of birth (Helsen et al., 2005).

In tennis and most sports, the different competition age groups are organized by grouping players born within the same 12-month period. Besides these "within one year" groupings, other age-groupings (e.g. annual age grouping and multiyear age bands) used in sport have been shown to generate different effects (e.g. within-year effects, constituent year effects and constant year effects). It is important to differentiate in-between the outcomes (Schorer et al., 2013), although regardless of the group system used, these cut-off dates are commonly used with the goal of reducing maturational differences and create homogenous competition groups allowing a more sensible coaching and evaluation of the athletes as well as to ensure that there is an equal chance of success and fair competition for all players in youth sports (Helsen et al., 2005; Musch and Grondin, 2001; Schorer et al., 2011).

However, research in different sports has found that athletes born early within the selection year are more likely to be selected for elite teams and talent development programs than those born later in the same year (Augste and Lames, 2011; Delorme and Raspaud, 2009; (Helsen et al., 2012; Mujika et al., 2009). This overrepresentation of relatively older athletes in youth sport has been labeled as the relative age effect (RAE) (Barnsley et al., 1985). Previous studies in tennis documented the existence of RAEs, with a skewed birth date distribution in top junior players as well as in senior players, with more players involved in elite development programs born in the first half of the calendar year (e.g., values ranging from 60 to 86%) than in the second half (Baxter-Jones et al., 1995; Dudink, 1994; Edgar and O'Donoghue, 2005b; Filipcic, 2001; Loffing et al., 2010). While the existence of RAEs has been associated with a loss of potential talent, eliminating these effects has proven challenging (Musch and Grondin, 2001). This appears to be related to difficulties in identifying potential causal mechanisms. One of the most recurrent suggested mechanisms is selection bias. That is, coaches mistakenly grant fewer opportunities (e.g., instruction, access to elite group or team) to relatively younger individuals than should be warranted by their latent ability or talent (Deaner et al., 2013).

In Germany, young talented tennis players are scouted and recruited to join regional and national training centers by coaches who are affiliated to the German Tennis Federation (DTB). Players are selected within the same 12-month period (from January 1st to December 31st) based on a repetitive observation of the players' technical/tactical abilities as well as their competitive

Received: 02 February 2015 / Accepted: 22 June 2015 / Published (online): 11 August 2015

performance. While selection bias is likely to be mediated by several interacting mechanisms, maturational factors are often the focus of study (Musch and Grondin, 2001). This maturational hypothesis is based on the large inter-individual biological differences within the same chronological age groups during childhood and adolescence assuming that players born close to the selection date profit from their advanced physical and cognitive maturation (Baxter-Jones and Sherar, 2007). Even small age differences (i.e., months) within an annual age-group can provide substantial advantage in physical and cognitive maturity (Baxter-Jones et al., 1995). In a sport like tennis, in which height, strength, speed, and power are important performance factors (Fernandez-Fernandez et al., 2009), relatively older children are more likely to dominate youth tennis, be identified as "more talented" and be selected to be part of elite teams (Baxter-Jones et al., 1995; Edgar and O'Donoghue, 2005a). It is therefore possible that in order to remain competitive and have chances to be selected for the next levels of talent development, relatively younger players within their age group have to match either anthropometrics and/or physical fitness performances of the older players. However, an investigation into the link between anthropometrics, physical fitness, and RAEs in young tennis players has not yet been conducted.

Therefore, the aims of the present study were: 1) to test the existence of RAE in young German male tennis players, 2) to examine if the potential RAE was influenced by age and/or skill level and 3) to investigate whether players who were born later in the selection year and were still selected into the elite squads were likely to be similar across a range of anthropometric and fitness attributes compared with those born earlier in the year.

Methods

Study design

Between the years 2009 and 2011, a sample of the 348 best male young players in Germany (from the national and regional selection groups) was evaluated using a battery of standard anthropometric and physical performance tests implemented by the DTB at the national level. Players were recruited from their respective regional federations and all federations in the country were tested. For the purpose of the present study, the players were grouped on the basis of chronological age into 1-year age categories (i.e., from January 1st to December 31st). The cohort spanned 6 years and included U12 (n = 70), U13 (n = 96), U14 (n = 57), U15 (n = 57), U16 (n = 32), U17 (n = 36) male tennis players. The players and parents were informed of all experimental procedures and written informed consent was completed before participation. The study was approved by the institutional research ethics committee and conformed to the recommendations of the Declaration of Helsinki (World Medical, 2013).

Participants

To assess the prevalence of RAEs in tennis, a substantial data set had to be collected from different sources. The birth dates of all male players affiliated with the German Tennis Federation (DTB) born between 1992 and 2000 (11 to 17 years old) (n = 120,851) were analyzed and this group was labeled as "licensed players". Among all these players, various subgroups were subsequently made and retained for further analyses (Table 1). The first subgroup, defined as "ranked players", included all male players with official ranking in the German youth ranking list (players aged 11-17 years old, n = 7,165). The second subgroup, defined as the "regional squad", was made up of the most talented players in each region (up to 30 players per region, aged 11 to 17 years old), selected by the regional federations coaching staff based on their technical/tactical abilities and competitive performance (n = 381). A third subgroup, defined as the "national squad", was drawn from the best of the 381 regional players (previous group), selected by the national federation coaching staff based on their technical/tactical abilities and competitive performance (n = 57, from 11 to 17 years old). In addition, the birth dates of the first 50 senior players of the national ranking (i.e., including the Davis Cup squad) were collected from the DTB database. Moreover, the birth distribution of the whole male German population born between 1992 and 2000 was extracted from the Federal Statistical Office ("Statistische Bundesamt") (https://www.destatis.de/DE/Startseite.html).

Table 1. Overview of the different groups analyzed

Group name	Group Definition	Sample Size (n)
German Population	The German male population born between 1992-2000 (U12-U18)	3216811
Licensed Players	All players affiliated to the German Tennis Federation (DTB) born between 1992 and 2000 (U12-U18).	120851
Ranked Players	All players having a ranking position on the Under 18-Youth ranking list born between 1992-2000 (U12-U18)	7165
Regional Squad	All players selected from the regional federation coaching staff as the most talented players born between 1992-2000 (U12-U18)	381
National Squad	All players selected from the national federation coaching staff as the most talented players born between 1992-2000 (U12-U18)	57
Senior Players	Top 50 senior players of the national ranking (including the Davis Cup team)	50

Procedures

All testing was completed in a three-week period, beginning at the end of September each year. Test sessions were undertaken between 14:00 and 20:30h and the players were assessed at their respective federation training centers. To ensure standardization of test administration across the entire study period, all tests were carried out in the same order and using the same testing devices and operators. All fitness tests were performed in an indoor tennis court (Rebound Ace surface). Testing began after a 15-min individual warm-up, which consisted of low-intensity forward, sideways, and backwards running, general dynamic mobility, multi-directional acceleration runs, skipping, and hopping exercises, and jumps of increasing intensity. The following physical performance tests were conducted.

Anthropometry. Sessions started with the measurement of players' body dimensions, which included body height, body mass, and sitting height. Body height was measured with a fixed stadiometer (±0.1 cm, Holtain Ltd., Crosswell, UK), sitting height with a purpose-built table (±0.1 cm, Holtain Ltd., Crosswell, UK), body mass with a digital scale (±0.1 kg, ADE Electronic Column Scales, Hamburg, Germany). For the prediction of the age of peak linear growth according to Mirwald et al. (2002), leg length was estimated by subtracting sitting height from body height.

Maturity Status. Pubertal timing was estimated according to the biological age of maturity of each individual as described by Mirwald et al. (2002). The age of peak linear growth (age at peak height velocity) is an indicator of somatic maturity representing the time of maximum growth in stature during adolescence (Mirwald et al., 2002). Biological age of maturity (years) was calculated by subtracting the chronological age at the time of measurement from the chronological peak-velocity age (Baxter-Jones and Sherar, 2007, Mirwald et al., 2002). Thus, a maturity age of -1.0 indicates that the player was measured 1 year before this peak velocity; a maturity of 0 indicates that the player was measured at the time of this peak velocity; and a maturity age of +1.0 indicates that the participant was measured 1 year after this peak velocity (Mendez-Villanueva et al., 2010).

RAE. To determine the existence of RAEs, player birth dates were firstly recorded to reflect their birth quartile (Q), according to the dates used for creating annual age groups. The cut-off date for the selection in German Tennis is January 1st and participants were divided into one of four groups. Therefore, Q1= players born in January, February and March; Q2 = players born April, May and June; Q3 = players born in July, August and September; and Q4 = players born in October, November and December.

Grip strength. Handgrip strength was measured using a hydraulic hand dynamometer (Baseline ®; Irvington, NY). The player was asked to perform a maximal voluntary contraction, standing with the dynamometer at one side (i.e., dominant hand) and gripping the dynamometer as hard as they could, for 3 s. This was repeated for each hand (i.e., dominant and non-dominant hand). The average of the 2 trials for each hand was considered to be the maximum voluntary handgrip strength (Innes, 2002).

Vertical jumping. Countermovement jumps (CMJ) without arm swing were performed on a contact platform (Haynl Elektronik, Germany) according to Bosco et al. (1983). Each player performed 2 maximal CMJs interspersed with 45 seconds of passive recovery, and the best jump (i.e., highest height attained) was retained for further analysis (Bosco et al., 1983).

Linear sprint. Time during a 20-m dash in a straight line was measured by means of single beam photocell gates placed 1.0 m above the ground level (Sportronic TS01-R04, Leutenbach-Nellmersbach, Germany). Each sprint was initiated from an individually chosen standing position, 50 cm behind the photocell gate, which started a digital timer. Each player performed 2 maximal 20-m sprints interspersed with 3 minutes of passive recovery, and the fastest time achieved was retained.

Serve velocity. A radar gun (Stalker Professional Sports Radar, Radar Sales, Plymouth, MN) was used to measure first-serve. The radar gun was positioned on the center of the baseline, 4 m behind the server, aligned with the approximate height of ball contact and pointing down the center of the court. The serves for subjects who were right-handed served to the left serve box (from the right) and the ones who were left-handed served at the right serve box (from the left). Athletes were instructed to perform eight maximal serves down the "T" (center line). A target area (150cm x 60cm) was placed into the serve box. Shots landing within the target area were given two points, serving into the serve box was counted one point and balls landing outside the serve box were associated with o points. A total score was recorded for each trail. The average speed was used for further analysis.

Hit and Turn Tennis Test. The Hit and Turn Test was developed as an acoustically controlled progressive on-court fitness test for tennis players, which can be performed simultaneously by several players (Ferrauti et al., 2011). The test involves specific movements along the baseline (i.e., side steps and running), combined with forehand and backhand stroke simulations at the doubles court corner (distance 11.0 m). At the beginning of each test level, the players stand with their racket in a frontal position in the middle of the baseline. Upon hearing a signal, the player turns sideways and runs to the prescribed (i.e., by a CD player) backhand or forehand corner. After making their shot, they return to the middle of the court using side steps or crossover steps (while looking at the net). When passing the middle of the baseline again, they turn sideways and continue to run to the opponent's opposite corner. The end of the test was considered when players fail to reach the cones in time or was no longer able to fulfill the specific movement pattern. Maximal completed level was used for the determination of the tennis-specific aerobic fitness.

Statistical analyses

Chi-square tests were used to test the observed and expected birth distribution across the sample of players. As recommended by Delorme and Raspaud (2009), all players affiliated to the German Tennis Federation (i.e., "licensed players") were used as the theoretical expected distribution (Delorme and Raspaud, 2009). In separate steps, all "ranked players", "regional squad" and "national squad" players were taken as the observed distribution. Anthropometrical and fitness variables were reported as mean and standard deviation (± SD). A one-way analysis of variance ANOVA was used to compare all anthropometrical and fitness variables across birth quarters for each age group. In addition, the standardized difference or effect sizes (ES) and the 90% confident intervals between the first and fourth quarter were calculated for each parameter. Threshold values for Cohen ES statistic were > 0.2 (small), 0.5 (moderate) and > 0.8 (large) (Cohen,

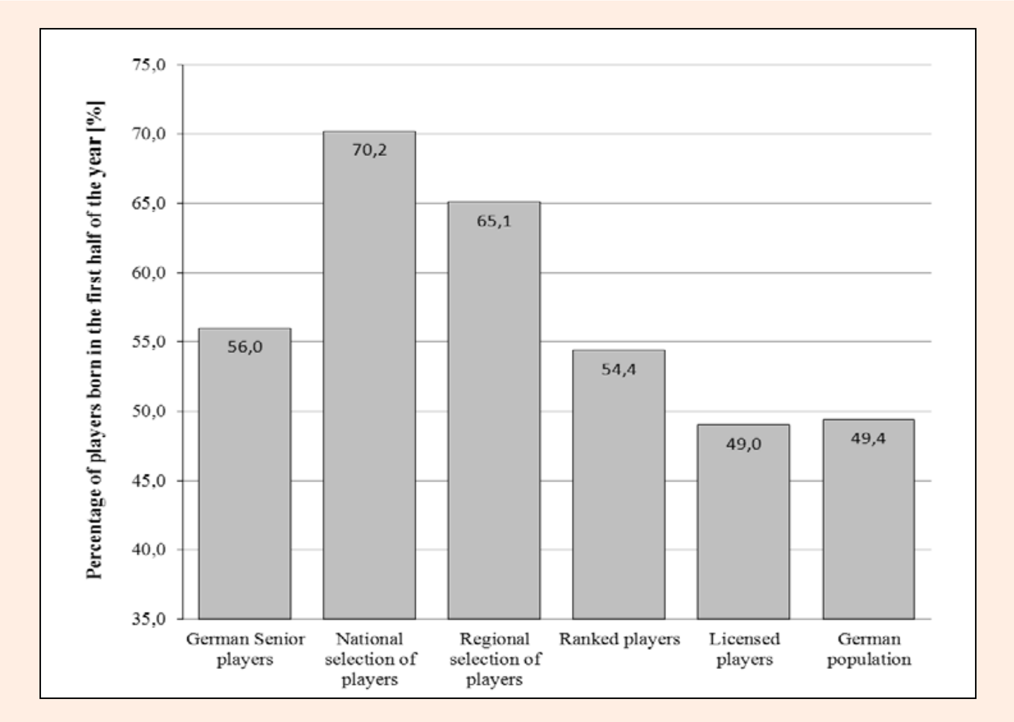

Figure 1. Representation of the different populations analyzed (tennis players and German population) born in the first half of the year.

1988). All calculations were performed using Microsoft Excel (Microsoft, Seattle, Washington, USA) and SPSS (version 20.0, SPSS Inc., Chicago, Ill., USA) and the level of significance was set at $p < 0.05$.

Results

The distribution of birth dates in the analyzed tennis players as well as the corresponding German population is shown in Table 2 and Figure 1. Figure 1 shows the percentage of males with different playing statuses born in the first half of the year, and the birth distribution of the German Top 50 senior players (including the Davis Cup team). There is a balanced distribution of the German population (49.5% born in the first half of the year (1^{stHY}) and 50.5% born in the second half of the year (2^{ndHY}), respectively). Similarly, a balanced distribution of "licensed players" (49.0% and 51.0% in the 1^{stHY} vs. the 2^{ndHY}, respectively) was observed. A moderate bias toward the 1^{stHY} was observed for "ranked players" (54.4% and 45.7% for the 1^{stHY} vs. the 2^{ndHY}, respectively). On the contrary, 65.1% of players of the "regional squad" were born in the first half (1^{stHY}) of the year, and 34.9% in the second half (2^{ndHY}). For the "national squad", the birth months were even more skewed towards the 1^{stHY} (70.2%) compared to the 2^{ndHY} (29.8%) (Figure 1).

When the "licensed players" were used as the expected distribution (Table 2), results showed significant differences between birth quartiles (*p* values ranging from < .001 to .03 for all age groups) with more players born in the first quarters of the year.

Results regarding the anthropometrical characteristics of the regional selected junior players compared across the four birth quarters of each age category are presented in Table 3. Results showed significant differences between quartiles only in some parameters and age groups ($p < .05$; effect sizes ranging from 0.06 to 1.28) in APHV (U12), years from/to APHV (U14 and U15), height (U14 and U15), body mass (U14) and body mass index (U13, U14 and U17).

Table 4 shows the results of the different physical fitness performance tests. There were significant differences between quartiles in grip strength (U13; Q1>Q4) and serve velocity (U12; Q4>Q2), while there were no differences in CMJ, 20 m sprint and Hit and Turn test between any age group.

Discussion

The aims of the present study were to test the existence of RAEs in young German male tennis players and to examine if these effects were influenced by age and/or skill level. A further aim was to investigate whether players born later in the selection year but still selected into the elite squads were likely to be similar across a range of anthropometric and fitness attributes compared with those born earlier in the year. The main findings of the present study were as follows: 1) an uneven birth distribution was present in German youth competitive tennis; 2) the observed effect was present in all of the age groups analyzed and more pronounced with an increased competition level in youth players; 3) the RAE was less apparent at elite senior level; 4) players born later in the selection year and still selected into the elite squads were likely to be similar across a range of anthropometric and fitness attributes compared with those born earlier in the year.

In order to accurately examine the birth

Table 2. Season of birth distribution of young male tennis players and the corresponding German population.

Age group	Status	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)	n	p
U12	National selection	6 (54.6)	2 (18.2)	0 (0.0)	3 (27.3)	11	
	Regional selection	38 (41.9)	22 (26.9)	20 (22.9)	9 (8.3)	89	.001
	Ranked players	501 (30.0)	444 (26.5)	417 (24.5)	325 (19.0)	1687	.000
	Listed players	5987 (25.2)	6110 (25.7)	6354 (26.7)	5364 (22.5)	23815	
	German population	196281 (24.9)	196644 (24.9)	210187 (26.6)	186507 (23.6)	805940	
U14	National selection	11 (44.0)	5 (20.0)	6 (24.0)	3 (12.0)	25	
	Regional selection	52 (38.5)	36 (26.9)	32 (22.6)	16 (12.0)	136	.001
	Ranked players	694 (32.5)	507 (23.5)	530 (24.6)	424 (19.5)	2155	.000
	Listed players	7974 (25.0)	7916 (25.0)	8530 (26.7)	7519 (23.6)	31939	
	German population	202693 (24.7)	204780 (25.0)	219002 (26.7)	193396 (23.6)	801381	
U16	National selection	5 (35.7)	7 (50.0)	1 (7.1)	1 (7.1)	14	
	Regional selection	34 (36.3)	25 (26.2)	19 (20.0)	16 (17.3)	94	.016
	Ranked players	495 (28.0)	436 (24.7)	441 (24.9)	397 (22.4)	1769	.000
	Listed players	7987 (23.8)	8158 (24.3)	8999 (26.8)	8456 (25.2)	33600	
	German population	193793 (24.2)	193239 (24.1)	215388 (26.9)	198961 (24.8)	819871	
U18	National selection	2 (28.6)	2 (28.6)	1 (14.3)	2 (28.6)	7	
	Regional selection	21 (34.1)	20 (34.6)	13 (19.3)	8 (12.0)	62	.031
	Ranked players	429 (27.6)	389 (25.0)	388 (24.9)	348 (22.4)	1554	.001
	Listed players	7454 (23.7)	7620 (24.2)	8580 (27.2)	7843 (24.9)	31497	
	German population	201252 (25.0)	202051 (25.1)	212213 (26.3)	190424 (23.6)	789619	
All age groups pooled together	National selection	24 (42.1)	16 (28.1)	8 (14.0)	9 (15.8)	57	.011
	Regional selection	145 (38.1)	103 (27.0)	84 (22.1)	49 (12.9)	381	.000
	Ranked players	2119 (29.6)	1776 (24.8)	1776 (24.8)	1494 (20.9)	7165	.000
	Listed players	29402 (24.3)	29804 (24.7)	32463 (26.9)	29182 (24.2)	120851	
	German population	794019 (24.7)	796714 (24.8)	856790 (26.6)	769288 (23.9)	3216811	

U12-U18: under 12 to under 18: Q_1-Q_4: first quarter to fourth quarter; $p < 0.05$: significant differences compared with licensed players

distribution of players, and for a precise measurement of a potential RAE, we followed the suggestions of Delorme and Raspaud (2009). These authors suggested that it is necessary to analyze all licensed players as the expected distribution, rather than to use the national population, since there might be already existing differences and there could be a misinterpretation of the results (Delorme and Raspaud, 2009). Therefore, if an asymmetric distribution is found among all licensed players, it would not be surprising to find the same tendency of distribution also among higher level players (i.e., regional and national squads). Thus, despite licensed players showing a balanced distribution, results showed that relative age effects exist in the regional and national squads, with a greater percentage of players born in the 1stQ (Table 2). Results are in line with previous research analyzing the birth dates of tennis players (e.g., 12 to 18 years old), with players born in the 1stHY accounting for 60 to 86% of the whole population analyzed (Baxter-Jones et al., 1995; Edgar and O'Donoghue, 2005b; Filipcic, 2001). Also, when ranked players were analyzed (7,165 players aged 10-17 years old), results showed significantly more players born in the 1stQ than in the last quarter of the year. Although the bias was less pronounced here (54.0%) than in the regional (65.1%) and national squads (70.2%), we can speculate that among these ranked players, there is a process of "self-elimination" in the later born players, since the selection of this group is not based on the decision of coaches and talent scouts, as in the regional and national groups. Although the causes for this self-adjusting distribution seem to be multifaceted and not clearly understood, some researchers from other sports speculate that this self-adjusting distribution could be provoked by a possible drop out of late born players as they might experience more situations of failure or inferiority, losing the ambition to compete and therefore withdraw from competitive tournaments (Delorme et al., 2010).

Analyzing the possible age related differences regarding RAEs, the findings revealed a skewed distribution of birth dates over the age categories analyzed (i.e., U12 to U18; Table 2) towards an earlier birth date. However, although the skewed distribution is still evident and an effect is more prevalent at younger ages, it seems that there is a tendency showing that the relative proportion of players born in the first quarters of the year diminishes from U12 to U18, also in the national group (i.e., 54.6% of the players born in the 1stQ in U12 and 28.0% in U18). Previous research in other sports investigating age as a moderator of risk found a progressively increased effect from the child (Under 10 years) age range to the adolescent (15-18 years) category, before decreasing at the senior (>19 years) age category (Cobley et al., 2009). Interestingly, this declining tendency is found when senior players (first 50 players in the DTB ranking list) are compared with the junior national squad players (56% of the players born in the 1stHY and 44% in the 2ndHY). These results are in agreement with previous research examining team sport athletes. Although the mechanisms for this age-related effect are not known, the relative advantage of total life experience is reduced as players get older (e.g., in 12-year old players, an 11-month difference in age represents ~10% of total life experience, while in 18-year old players that means ~5%).

Regarding competitive level, our results show that the percentage of players born in the 1stHY increased according to the selection level in youth tennis players (i.e., from all licensed players to the national selection of players) (Figure 1). Present results, however, concur with

Table 3. Biological maturity, anthropometric characteristics and ranking positions of youth elite tennis players according to birth distribution.

	Age Group	1^{st} Q	2^{nd} Q	3^{rd} Q	4^{th} Q	P	Post hoc	ES ± (90%CI)
APHV [year]	**U12**	13.8 ± 0.5	13.8 ± 0.3	13.4 ± 0.4	13.2 ± 0.5	.001	Q1>Q3;Q4 Q2>Q4	1.28 (-.25; .97)
	U13	14.2 ± 0.6	13.8 ± 0.5	13.9 ± 0.5	13.7 ± 0.3	.358	n.d	.36 (-0.48; 1.41)
	U14	13.7 ± 0.8	13.8 ± 0.6	13.8 ± 0.6	14.1 ± 0.5	.532	n.d.	.56 (-0.95; 0.11)
	U15	13.8 ± 0.6	13.9 ± 0.6	14.0 ± 0.8	13.8 ± 0.7	.843	n.d.	.06 (-0.29; 0.39)
	U16	13.8 ± 0.5	13.8 ± 0.7	13.4 ± 0.3	13.3 ± 0.6	.170	n.d.	.70 (-0.07; 0.77)
	U17	14.0 ± 0.6	13.9 ± 0.5	13.9 ± 0.6	13.5 ± 0.4	.576	n.d.	.74 (-0.14; 1.08)
Years from/to APHV [year]	**U12**	-2.07 ± 0.5	-2.3 ± 0.3	-2.2 ± 0.4	-2.2 ± 0.5	.294	n.d.	.31 (-0.21; 0.51)
	U13	-1.7 ± 1.7	-1.4 ± 0.5	-1.7 ± 0.5	-1.8± 0.3	.731	n.d.	.05 (-0.64; 1.18)
	U14	0.0 ± 0.8	-0.3 ± 0.6	-0.5 ± 0.6	-1.1 ± 0.4	.001	Q1;Q2>Q4	1.58 (0.72; 1.75)
	U15	0.9 ± 0.6	0.5 ± 0.7	0.1 ± 0.9	0.2 ± 0.6	.013	Q1>Q3;Q4	1.06 (0.30; 1.10)
	U16	2.0 ± 0.5	1.7 ± 0.7	1.8 ± 0.3	1.6 ± 0.6	.619	n.d.	.60 (-0.12; 0.82)
	U17	2.8 ± 0.6	2.6 ± 0.5	2.3 ± 0.6	2.4 ± 0.5	.334	n.d.	.53 (-0.42; 0.82)
Height [cm]	**U12**	151.0 ± 7.5	148.0 ± 5.4	150.0 ± 8.0	151.2 ± 9.7	.641	n.d.	.03 (-6.25; 5.77)
	U13	157.3 ± 8.1	157.1 ± 8.6	155.6 ± 6.4	154.0 ± 4.7	.604	n.d.	.40 (-1.17: 7.78)
	U14	167.7 ± 7.5	165.5 ± 6.5	164.4 ± 8.1	157.5 ± 7.7	.024	Q1>Q4	1.31 (4.55; 15.79)
	U15	174.7 ± 6.5	170.4 ± 8.2	167.2 ± 10.0	168.8 ± 7.0	.044	n.d.	.88 (1.84; 10.13)
	U16	178.2 ± 5.4	179.3 ± 8.7	179.6 ± 4.9	180.5 ± 6.1	.898	n.d.	.39 (-7.32; 2.56)
	U17	181.2 ± 4.9	180.6 ± 3.8	178.4 ± 6.2	180.0 ± 6.3	.677	n.d.	.22 (-4.09; 6.51)
Body mass [kg]	**U12**	39.5 ± 5.9	36.3 ± 3.0	39.8 ± 6.3	40.8 ± 5.6	.192	n.d.	.22 (-5.77; 3.15)
	U13	45.5 ± 6.9	43.9 ± 8.7	41.3 ± 4.9	40.2 ± 3.6	.067	n.d.	.73 (1.50; 9.09)
	U14	54.0 ± 8.8	50.8 ± 6.4	49.9 ± 8.4	42.2 ± 4.6	.009	Q1>Q4	1.43 (5.82; 17.80)
	U15	61.2 ± 8.5	57.5 ± 9.4	55.0 ± 11.2	56.7 ± 8.2	.292	n.d.	.52 (-0.75; 9.63)
	U16	65.7 ± 5.5	64.9 ± 8.0	69.7 ± 4.1	67.5 ± 9.7	.565	n.d.	.22 (-8.16; 4.68)
	U17	73.0 ± 6.3	67.9 ± 4.8	71.4 ± 7.0	72.4 ± 9.1	.243	n.d.	.09 (-6.43; 7.73)
Ranking [national U18]	**U12**	1838.0 ± 742.7	1918.0 ± 889.8	2255.4 ± 917.1	1445.0 ± 932.1	.177	n.d.	.49 (-197.8; 983.9)
	U13	981.5 ± 463.3	1132.8 ± 557.3	1195.8 ± 751.7	891.0 ± 286.6	.341	n.d.	.16 (-167.5; 348.5)
	U14	726.1 ± 514.5	833.4 ± 927.8	887.0 ± 968.3	646.3 ± 317.7	.888	n.d.	.16 (-274.8; 434.4)
	U15	325.7 ± 240.0	405.6 ± 542.5	367.2 ± 157.3	455.7 ± 460.7	.799	n.d.	.38 (-339.5; 79.6)
	U16	120.2 ± 69.3	153.6 ± 112.3	360.1 ± 338.9	201.6 ± 206.6	.104	n.d.	.55 (-203.4; 40.7)
	U17	72.8 ± 91.1	192.6 ± 372.7	152.0 ± 163.6	102.5 ± 134.6	.664	n.d.	.28 (-133.4; 74.0)

APHV: estimated age from/to peak height velocity; U12-U17: under 12 to under 17: Q_1-Q_4: first quarter to fourth quarter; ES: effect size; 90%CI: 90% confidence intervals

previous research where the magnitude of the RAEs was greater at higher competitive level in soccer players (Mujika et al., 2009; Sherar et al., 2007). Moreover, and according to the present data, it can be speculated that in the transition from junior to senior professional level a greater number of relatively older players are more likely to drop-out, which has also been reported in handball and soccer (Baker et al., 2010; Cobley et al., 2008). Therefore, in the long term, the former disadvantage might turn into an advantage as relatively younger and late mature players might develop superior technical and tactical skills once they "survive" the talent detection and development system (Schorer et al., 2011).

Overall, no systematic differences were observed in any of the anthropometrical characteristics between the players born in different quarters (Table 3). However, there were some substantial differences in some variables in certain age groups, which should be noted. For example, in the U12 group, later born players have their APHV earlier (0.61 years) than their relatively older peers (i.e., 13.78 vs. 13.17 for players born in the 1stQ vs. 4thQ, respectively), possibly compensating the "disadvantage" of being relatively young with an earlier age for onset of puberty. On the contrary, in U14 and U15 players, those players born in the 1stQ already achieved their respective ages of PHV, while players born in the 4thQ were almost one year behind them (i.e., APHV in U14: 0.01 vs. -1.23 for players born in the 1stQ vs. 4thQ, respectively). Also, in the U14 and U15 players and in the U13 and U14, players born in the 1stQ were taller and heavier than their 4thQ born peers. Whilst these tendencies in anthropometry are likely to be practically important (e.g., relatively taller players would be able to serve faster (Vaverka and Cernosek, 2013), they were not accompanied by superior physical fitness (see below), which might have enabled them to minimize the potential advantages associated to superior anthropometrical parameters.

No systematic differences were found in any of the physical fitness parameters analyzed when comparing players born across different quarters of the year, supporting the hypothesis that selected talented players born later in the year presented similar physical fitness values than their earlier born peers. Similarly, previous research conducted in soccer, showed that players born later in the selection year, and selected into the elite teams, had similar physical characteristics than their relatively older peers (Deprez et al., 2012).

There were some limitations to this type of study. Most notably, we tested the players only once during the season. Longitudinal data of the same players during multiple years might have yield different results since some physical fitness performance and anthropometrical measures have been shown to be unstable throughout adolescence (Buchheit and Mendez-Villanueva, 2013). The regression equations used to estimate the pubertal timing according to Mirwald et al. (2002) were calculated

Table 4. **Fitness characteristics of youth elite tennis players according to birth distribution.**

	Age Group	1st Q	2nd Q	3rd Q	4th Q	P	Post hoc	ES ± (90%CI)
Grip strength D [kg]	U12	22.0 ± 3.4	21.7 ± 2.8	22.4 ± 4.1	23.8 ± 5.0	.786	n.d.	48 (-4.60; 1.02)
	U13	26.5 ± 3.9	25.2 ± 5.2	23.1 ± 3.7	23.3 ± 2.6	.030	Q1>Q3	85 (.36; 4.80)
	U14	33.1 ± 6.7	30.9 ± 7.2	30.3 ± 5.6	26.7 ± 3.3	.186	n.d.	01 (1.88; 10.98)
	U15	38.9 ± 7.7	36.9 ± 8.2	33.0 ± 7.2	35.0 ± 8.5	.251	n.d.	48 (-1.05; 8.87)
	U16	44.8 ± 7.3	44.0 ± 8.7	49.7 ± 7.8	47.3 ± 5.3	.483	n.d.	36 (-8.14; 3.16)
	U17	51.8 ± 6.4	46.1 ± 7.3	49.1 ± 6.1	49.0 ± 3.9	.233	n.d.	45 (-3.24; 8.87)
CMJ [cm]	U12	28.5 ± 3.3	29.1 ± 4.4	29.3 ± 4.5	30.5 ± 4.9	.702	n.d.	56 (-4.19; .09)
	U13	30.7 ± 3.8	30.9 ± 4.1	29.1 ± 2.9	29.0 ± 4.0	.271	n.d.	44 (-.59; 3.99)
	U14	32.7 ± 3.1	32.4 ± 4.9	30.9 ± 4.6	34.8 ± 2.6	.261	n.d.	69 (-4.32; 0.11)
	U15	35.3 ± 3.5	35.2 ± 3.4	33.6 ± 3.2	32.8 ± 3.9	.193	n.d.	66 (.21; 4.77)
	U16	36.6 ± 4.9	37.3 ± 4.3	39.0 ± 3.2	36.9 ± 3.3	.658	n.d.	07(-4.03; 3.41)
	U17	38.4 ± 4.5	36.3 ± 3.8	41.5 ± 3.7	37.2 ± 1.2	.061	n.d.	29 (-2.88; 5.36)
20m Sprint [s]	U12	3.60 ± 0.15	3.61 ± 0.18	3.61 ± 0.13	3.52 ± 0.12	.544	n.d.	56 (-,03; .20)
	U13	3.51 ± 0.16	3.50 ± 0.16	3.59 ± 0.10	3.51 ± 0.17	.277	n.d.	16 (-.10; .09)
	U14	3.35 ± 0.14	3.46 ± 0.16	3.45 ± 0.21	3.45 ± 0.15	.152	n.d.	67 (-.21;.01)
	U15	3.29 ± 0.17	3.33 ± 0.15	3.34 ± 0.18	3.37 ± 0.15	.616	n.d.	47 (-.18; .02)
	U16	3.18 ± 0.11	3.18 ± 0.13	3.19 ± 0.07	3.18 ± 0.13	.996	n.d.	02 (-.10; .10)
	U17	3.09 ± 0.11	3.18 ± 0.14	3.10 ± 0.10	3.06 ± 0.13	.234	n.d.	28 (-.09; .15)
Serve velocity [km/h]	U12	123.7 ± 10.9	117.0 ± 8.1	120.2 ± 7.4	130.9 ± 4.5	.012	Q2<Q4	69 (14,9; .56)
	U13	134.2 ± 8.4	130.6 ± 10.0	132.7 ± 8.9	132.4 ± 8.9	.456	n.d.	11 (-3.14; 6.86)
	U14	148.2 ± 10.7	146.3 ± 13.4	136.8 ± 16.5	140.3 ± 5.1	.088	n.d.	80 (.76; 15.18)
	U15	161.7 ± 14.7	155.2 ± 13.3	148.00± 9.4	156.0 ± 11.6	.106	n.d.	41 (-2.69; 14.20)
	U16	172.2 ± 5.1	168.0 ± 10.7	171.20± 7.4	170.7 ± 10.8	.794	n.d.	17 (-5.33; 8.34)
	U17	176.7 ± 10.0	169.2 ± 9.5	177.9 ± 13.5	175.1 ± 11.0	.269	n.d.	15 (-8.79; 12.03)
Hit & Turn Test [level]	U12	13.3 ± 1.8	11.6 ± 2.5	12.6 ± 2.1	13.0 ± 2.6	.080	n.d.	18 (-1.11; 1.82)
	U13	13.5 ± 2.1	13.7 ± 1.8	14.3 ± 1.4	14.2 ± 2.9	.522	n.d.	28 (-1,46; 1.23)
	U14	14.7 ± 2.3	15.2 ± 1.7	14.4 ± 2.5	14.5 ± 2.2	.799	n.d.	06 (-1.54; 1.83)
	U15	16.0 ± 1.8	15.6 ± 1.6	16.4 ± 1.3	15.9 ± 1.4	.723	n.d.	06 (-.95; 1.15)
	U16	17.5 ± 1.8	16.9 ± 0.7	16.6 ± 1.1	16.5 ± 1.0	.380	n.d.	63 (-.30; 2.27)
	U17	17.7 ± 1.8	16.6 ± 2.0	16.3 ± 2.4	17.4 ± 1.6	.422	n.d.	20 (-1.43; 2.21)

D: dominant hand; CMJ: countermovement jump; U12-U17: under 12 to under 17: Q_1-Q_4: first quarter to fourth quarter; ES: effect size; 90%CI: 90% confidence intervals

on a sample of Canadian children. Since we used non-Canadian children, this might have an effect on the outcomes.

Conclusion

The results of the present study show that RAEs exist in the selection of youth tennis players in Germany, with a greater percentage of players analyzed born in the 1st Quarter compared to all licensed tennis players in the country, and more pronounced with an increased competition level in youth players. However, players selected into the higher competitive groups (regional and national) were physically homogenous regardless of relative age. While the selection process of the present elite tennis players seems to follow the trend observed in other team sports as soccer or basketball, with early born players being more selected at junior levels, especially at younger ages and at higher playing standards (i.e., national selection), the reasons for this “over-selection” appear to be related with current performance rather than potential progression, as a RAE is much less evident in senior players. Players born later in the selection year and still selected in elite squads were likely to be similar across a range of physical fitness attributes compared with those born earlier in the year. Results of the present study may help improve the current selection policies in elite tennis in Germany, facilitating the selection of greater number of players born in the latter part of the year.

Acknowledgements

The authors would like to especially thank Peter Pfannkoch (German Tennis Federation) for his support within the project.

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Key points

- RAEs exist in the selection of youth tennis players in Germany, a greater percentage of players analyzed was born in the 1st quarter compared to all licensed tennis players in the country, and more pronounced with an increased competition level in youth players.
- Players born later in the selection year and still selected in elite squads were likely to be similar across a range of physical fitness attributes compared with those born earlier in the year.
- The selection process should be reevaluated and changed to reduce the impact of RAEs on tennis players.

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