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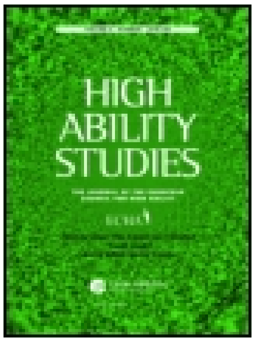

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ORIGINAL ARTICLE

The interaction between within-year and between-year effects across ages in elite table tennis in international and national contexts – A further exploration of relative age effects in sports

Irene R. Faber[a,b,c*], Meihan Liu[d*], Valérian Cece[e], Ren Jie[d], Guillaume Martinent[e], Jörg Schorer[a] and Marije T. Elferink-Gemser[f]

[a]Institute of Sport Science, University of Oldenburg, Oldenburg, Germany; [b]Faculty of Physical Activity and Health, Saxion University of Applied Sciences, Enschede, The Netherlands; [c]International Table Tennis Federation, Lausanne, Switzerland; [d]China table tennis college, Shanghai University of Sport, Shanghai, China; [e]Laboratory of Vulnerabilities and Innovation in Sport (EA 7428), University of Lyon, University of Claude Bernard Lyon, Lyon, France; [f]Centre for Human Movement Sciences, University Medical Centre Groningen, University of Groningen, Groningen, The Netherlands

ABSTRACT

Although relative age effects in sports have been studied worldwide, the underlying mechanisms are still under debate. This study adds to the existing knowledge by providing a further exploration of the within-year and between-year effects and their possible interaction in an individual skill/technique based sport: table tennis. Data of male and female elite players across ages (U15, U18, U21, and senior) were collected from the ranking lists in international (world and Europe) and national contexts (France and the Netherlands). A multi-way frequency analysis per subsample revealed (1) no interaction effects; (2) significant within-year and between-year effects for the U15 players in the international context and male French players; (3) a significant within-year effect in the French U18 category; (4) a significant within-year effect in female European U21; and (5) no within-year effects in the senior category. Table tennis seems to be at risk for within-year and between-year effects specifically within the context of high competitive level for younger players (U15, males, and females), but not for interactions between these effects. Future research should reveal the development of the RAEs over time in a longitudinal study, evaluate influencing constraints, and innovative prevention solutions in a more comprehensive way.

KEYWORDS
Racquet sports; relative age effect; table tennis; youth

Introduction

The relative age effect (RAE) in sports is typically described as a situation of inhomogeneous distribution of the players' birth dates within one age

CONTACT tlsb -0.02w?>CONTACT Irene R. Faber irene.faber@uol.de Institute of Sport Science, University of Oldenburg, P.O. Box 2503, Oldenburg 26111, Germany; Meihan Liu liumeihancm@163.com China Table Tennis College, Shanghai University of Sports, Hengren Road, No.200, Shanghai 200438, China

*These authors share first authorship.

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category. In this case, the observed birth distribution differs from the expected one. In most sports this is displayed as an overrepresentation of the relatively older players who are born early after the cut-off date (Musch & Grondin, 2001). RAEs in youth sports can lead to an unintended unfairness regarding training, support, and competition in sports and a waste of potential (talented) youth players (Musch & Grondin, 2001). For that reason, it is important to better recognize RAEs and understand the underlying mechanisms. Hypothesizing about the existence of RAEs in youth sports and the underlying mechanism is, however, not straightforward (Wattie, Schorer, & Baker, 2015). It is a challenge to unravel the etiology and influences in different sports within a certain context since many factors play a role.

Recently, Wattie et al. (2015) proposed a theoretical framework to facilitate the understanding of RAEs in sports. They based their framework on Newell's constraints-based model including three interacting types of constraints: individual, task, and environmental constraints (Newell, 1986). A player's birth date, physical maturation, and size, sex and handedness are suggested as individual constraints within the framework. Task constraints include the type of sport and level of competitive play. Cultural popularity, social norms, policies, and development programs in sports and family influences are examples of the environmental constraints. Besides these three types of constraints also the RAEs themselves are proposed as elements within the model that can interact bi-directionally with the constraints as soon as they exist within a context. Finally, change over time is also added as a component as all constraints can develop over time. This frame-work can be used as a starting-point when studying RAEs in a certain sport.

Classically, RAE studies in youth sports examine the within-year effects in relatively physical demanding team sports like ice-hockey, soccer, and basketball (Helsen et al., 2016; Musch & Grondin, 2001; Smith, Weir, Till, Romann, Cobley, 2018). The frequently existing within-years effects in these sports are mostly explained by the maturational-selection hypothesis (Smith et al., 2018), which represents the interactive effect of the individual, task and environmental constraints. The relative older youth players benefit from their physical advantages compared to their relatively younger peers (Helsen et al., 2016). These individual characteristics increase the chances of success in their sport and of being selected for a specific program by a scout/coach. This mechanism is proposed to be reinforced by possible cognitive advantages in the relatively older youth players (Crawford, Dearden, & Meghir, 2010; Helsen et al., 2016; Sykes, Bell, & Rodeiro, 2009) and the psychological and sociocultural mechanisms (Hancock, Adler, & Côté, 2013). It has been shown that the within-year effects vary between sports, competition levels, sexes, and age categories

(Baker, Schorer, Cobley, Bräutigem, Büsch, 2009; Schorer, Cobley, Büsch, Bräutigam, & Baker, 2009). It is suggested that a more physical/endurance demanding sport, a higher amount of competitors and stronger competition increases the risk for RAEs (Schorer et al., 2015; Smith et al., 2018), RAEs are more prevalent in male players compared to female peers and RAEs are especially recognized in the pre-pubertal period (Cobley, Baker, Wattie, & McKenna, 2009).

In addition to this, it is important to realize that besides the generally studied within-year effects, also between-year effects, i.e. constituent and constant year effects, need to be considered as a part of the RAE (Schorer, Wattie, & Baker, 2013; Steingröver, Wattie, Baker, Helsen, & Schorer, 2017). Constituent year effects refer to the effects that can be observed between birth cohorts within a multiyear dynamic age category (Medic, Starkes, & Young, 2007; Wattie, Cobley, Baker, 2008). In a multiyear dynamic age category, the relative age of players belonging to a certain birth cohort changes every season; e.g. in an age category including two one-year birth cohorts, players will start as the youngest cohort in the first year, and will be the oldest cohort in the next year. Constant year effects are equivalent to the constituent year effects with the essential difference that the multiyear age category is fixed; players of the youngest birth cohort will remain the youngest over time. Typically, the constituent and constant year effects show that the younger birth cohort is under-represented within the age category compared to the older birth cohort(s) (Lames, Auguste, Dreckmann, Görsdorf, Schimanski, 2008; Schorer et al., 2013; Steingröver et al., 2017). The presence of more variations of RAEs (i.e. within-year and between-year effects) in a certain context, which even may interact, enhances the complexity of RAEs and their mechanisms even further (Wattie et al., 2015).

Because of this complexity, the aims of this study were multifold. The most important aim was to investigate the interaction of within-year and between-year effects in an individual and skill/technique based sport, in this case table tennis. Previous research on within-year effects in table tennis have shown mixed results (Faber & Schorer, 2018; Liu, Elferink-Gemser, Cece, Martinent, & Faber, 2017; Romann & Fuchslocher, 2014; Romann, Rössler, Javet, & Faude, 2018). In the recent studies of Faber et al. (2018) and Liu et al. (2017), within-year effects in elite Dutch, French, and Chinese table tennis youth were found. The studies of Romann's group, on the other hand, showed a reverse within-year effect in the basic population female Swiss table tennis players (10–20 years) with small effect sizes. The mixed results might be explained by the existence of an interaction effect (Steingrover et al., 2017), as well as the other factors mentioned. As shown for within-year effects, the interactions might be influenced by the national contexts (e.g. cultural importance) (Romann & Fuchlocher, 2014), the nature of sport (Smith et al., 2018), the level of competition (Baker et al., 2009; Schorer et al., 2015), the sex of the players (Schorer et al., 2009; Smith et al., 2018), the age groups under investigations (Cobley et al., 2009), and the interplay of these factors (Wattie et al., 2015).

In this study, the interaction of the within-year and between year effects is studied in elite table tennis in international and national contexts. Since this is the first exploration of the interaction of the RAEs in an individual and skill/technique based sport it seems premature to present a hypothesis. Yet, based on the previous outcomes in elite players (Faber & Schorer, 2018; Liu et al., 2017), it was hypothesized that the RAEs will be more prevalent in elite table tennis contexts with a strong competition level. Moreover, we suggested that RAEs will be more prevalent in the younger age categories as differences in physical and cognitive maturity and experiences at these ages are suggested to influence performance to a high extent (Cobley et al., 2009). In line with the previous studies, it was also hypothesized that the RAEs will be more apparent in male table tennis players as a result of the higher number of active competitive male players compared to their female peers (Cobley et al., 2009; Smith et al., 2018; Vincent & Glamser, 2006).

Method

Design

A cross-sectional approach was used to examine the interaction between the within-year and between-year (i.e. constituent) effects in the sport of table tennis in international (world and Europe) and national contexts (France and the Netherlands) with different competition levels (competition level from high to low: world, Europe, France, and the Netherlands) across ages for both male and female players. This study was conducted in full compliance with the declaration of Helsinki. All data were recorded in anonymous data sets that were made available by the International Table Tennis Federation (ITTF), the European Table Tennis Union (ETTU), the French Table Tennis Federation (FFTT), and the Netherlands Table Tennis Association (NTTA) from their archives.

Players

For the international contexts and France, the top 100 players were included for the age categories under 15 (U15), under 18 (U18), under 21 (U21), and senior (>21 years) when possible. Since the Netherlands has less players competing in table tennis, only the top 50 of this country was included for the same age categories when possible. The end rankings of the latest competition season within the specific context were used for this purpose; the ITTF world ranking list of December 2016 for the world, the ETTU European ranking list of August 2016 for Europe and the national ranking lists of June 2017 for France and the Netherlands.

Data collection and analysis

The birth month of each player was collected for analysis. These data were transferred into the accompanying birth quartile. The quartiles were determined periods of three months. Quartile 1 (Q1) represents the first period after the cut-off date (i.e. 1st of January in all contexts in this study), which covers the period from January to March. Quartile 2 (Q2) represents the second period from April to June, quartile 3 (Q3) the third period from July to September, and quartile 4 (Q4) the final period from October to December. The U15 age group officially includes two birth cohorts whereas the U18 and U21 both include three cohorts. The senior category covers more than 20 birth cohorts. Normally, the player's birthdate determines his/her age category for competition. Exceptions are made in case of excellent performance; younger players might be included in an older age category for competition. However, in this study all players' data were analyzed while using the official cut-off dates for each age category.

IBM SPSS Statistics 25 (IBM Corp., Armonk, New York, United States of America) was used for the statistical analyses. The observed birth date distributions per quartile and per birth cohort were calculated as percentage per subsample (i.e. per context, sex, and age category). A multi-way frequency analysis (Steingröver et al., 2017; Tabachnick & Fidell, 2013), including the calculation of the effect size (W) was used per subsample to test for the interaction and the main effects of the within-year and the between-year effect. An equal birth distribution across all quartiles and cohorts (i.e. years) was assumed for the analysis. Since the senior age category included players of a wide age range, only the within-year effect was analyzed for this age category. Alpha was set on 0.05 for all analyses.

Results

In total data of 800 players of the world ranking list and 709 of the European ranking list were included for the analyses concerning the international context. Data of 800 players were extracted from the French rankings and data of 391 players from the Dutch rankings for the national contexts' analyses. Players could be part of different subsamples (e.g. within the top 100 of the French, European, and World ranking). The full subsample of the intended top 100 or 50 could not be realized for the U15 and U21 European players and the U15 and U21 Dutch players, because the ranking list did not include this amount of players. In the U15 category in the world and European context also younger players were included. This involved between 0% and 27% of the subsamples.

Tables 1 and 2 present the within-year (quartiles) and between-year (birth cohorts) distributions per subsample and the outcomes of the interaction, the within-year and the between-year analyses for male and female players, respectively. Additionally, Figure 1 presents the effects sizes of the within-year and between-years effects for the U15, U18, and U21 of the different contexts. No significant interactions were found between the within-year and the between-year effect in both male and female players ($P > 0.05$). The observed birth distribution differed significantly from the expected equal distribution for both the within-year as the between-year effect in U15 players with small to medium effect sizes ($P < 0.05$; W between 0.25 and 0.32) in the international context. Only the between-year effect in the U15 male world ranked players did not meet the cut-off value for significance ($P = 0.054$; W = 0.19). In all cases, there was an overrepresentation of the relatively older players. The French and Dutch male U15 players followed the same trend, however only significance was reached for the French players with a medium effect size (i.e. within-year effect $P = 0.012$ (W = 0.33) and between-year effect $P = 0.003$ (W = 0.30)). The trend was also visible in female French U15 players, but no significant differences were found. In the U18 category only the France ranking list showed a significant within-year effect in both the male and female players with medium effect sizes ($P < 0.05$; male W = 0.34, female W = 0.38). Moreover, in the U21 category only a significant medium within-year effect was shown in the female European U21 ($P = 0.003$; W = 0.38). No within-year effects were present in the senior category.

Discussion

This study focused first on the interaction of the within-year and between-year effects in the individual and skill/technique based sport of table tennis. The results of this study showed no interaction effects between the within-year and between-year effects. In none of the subsamples, based on the players' sexes, competition contexts, and age categories, an interaction effect was revealed. Even the youngest age category (U15) within the international contexts with a strong competition level, which was considered to be most at risk for an interaction effect (Cobley et al., 2009), did not show interactions. These results are in contrast with previous findings in youth basketball in which interaction effects were for found for male U16 players (Steingröver et al., 2017). Possible explanation might lie in the constraints for table tennis and their interaction that differ from other sports (Wattie et al., 2015). First, table tennis is suggested to be more dependent on skills/techniques compared to other sports (Romann & Fuchlocher, 2014; Romann et al., 2018). Consequently, RAEs and their interaction might not be that

Table 1. Within-year and between-year effects of male elite players in international and national contexts.

Context (ranking date)	Age category	*n*	Q1	Q2	Q3	Q4	Within-year effect χ^2 (*p*)	Within-year effect *W*	Y1	Y2	Y3	Between-year effect[#] χ^2 (*p*)	Between-year effect[#] *W*	Interaction effect χ^2 (*p*)	Interaction effect *W*
World	U15	100	36	25	27	12	10.888 (0.012)*	0.32	53	35	(12[a])	3.708 (0.054)	0.19	5.631 (0.131)	0.24
(December 2016)	U18	100	33	22	22	23	3.239 (0.359)	0.18	43	32	25	4.903 (0.086)	0.22	3.025 (0.806)	0.17
	U21	100	28	29	24	19	2.567 (0.463)	0.16	29	42	29	3.259 (0.196)	0.18	8.158 (0.227)	0.29
	Senior	100	26	26	30	18	3.041 (0.385)	0.17	-	-	-	-		-	
Europe	U15	88	33	31	29	7	17.582 (0.001)*	0.45	58	34	(8[a])	5.507 (0.019)*	0.25	2.605 (0.457)	0.17
(August 2016)	U18	100	29	28	21	22	2.007 (0.571)	0.14	38	38	24	4.148 (0.126)	0.20	1.345 (0.969)	0.12
	U21	86	20	34	21	25	3.987 (0.263)	0.22	37	34	29	0.868 (0.648)	0.10	2.668 (0.849)	0.18
	Senior	100	28	24	28	20	1.762 (0.624)	0.13	-	-	-	-	-	-	-
France	U15	100	30	34	23	13	11.011 (0.012)*	0.33	65	35	-	9.140 (0.003)*	0.30	4.913 (0.178)	0.22
(July 2017)	U18	100	36	21	29	14	11.305 (0.010)*	0.34	30	37	33	0.738 (0.692)	0.09	5.595 (0.470)	0.24
	U21	100	25	28	22	25	0.722 (0.868)	0.08	35	34	31	0.877 (0.263)	0.09	9.786 (0.134)	0.31
	Senior	100	31	20	20	29	4.081 (0.253)	0.20	-	-	-	-	-	-	-
The Netherlands	U15	49	28	32	20	20	2.633 (0.452)	0.23	50	30	(20)	2.527 (0.112)	0.23	1.683 (0.641)	0.19
(July 2017)	U18	50	32	32	10	26	7.656 (0.054)	0.39	34	38	28	0.770 (0.680)	0.12	10.969 (0.089)	0.47
	U21	50	26	26	20	28	0.750 (0.861)	0.12	36	28	36	0.659 (0.719)	0.11	1.293 (0.972)	0.16
	Senior	50	18	24	30	28	1.682 (0.641)	0.18	-	-	-	-	-	-	-

Data for quartiles and years are percentage. Age-categories: U15: under 15, U18: under 18, U21: under 21 and senior ≥ 21. Q1: January–March, Q2: April–June, Q3: July–September, Q4: October–December. Y1: oldest cohort, Y2: second oldest cohort, Y3: youngest cohort (U15 officially includes only two cohorts). [#]The between-year effect is the constituent-year effect. *$p < 0.05$ indicating significance. [a]1 player who was one year younger.

Table 2. Within-year and between-year effects of female elite players in international and national contexts.

							Within-year effect					Between-year effect[#]		Interaction effect	
Context (ranking date)	Age category	*n*	Q1	Q2	Q3	Q4	χ^2 (*p*)	*W*	Y1	Y2	Y3	χ^2 (*p*)	*W*	χ^2 (*p*)	*W*
World	U15	100	40	26	21	13	12.796 (0.005)*	0.36	52	27	(21[b])	8.049 (0.005)*	0.28	1.896 (0.594)	0.14
(December 2016)	U18	100	27	28	30	15	6.117 (0.106)	0.25	37	30	33	0.739 (0.692)	0.09	4.300 (0.636)	0.21
	U21	100	25	30	23	22	1.479 (0.687)	0.12	30	33	37	0.738 (0.692)	0.09	8.661 (0.194)	0.29
	Senior	100	34	17	29	20	7.441 (0.059)	0.27	-	-	-	-	-	-	-
Europe	U15	84	44	22	17	17	11.555 (0.009)*	0.37	63	24	(12[a])	15.473 (<0.001)*	0.43	0.650 (0.885)	0.09
(August 2016)	U18	100	31	31	22	16	6.768 (0.080)	0.26	33	37	30	0.738 (0.692)	0.09	8.601 (0.197)	0.29
	U21	51	45	22	23	10	13.074 (0.004)*	0.51	35	26	39	1.584 (0.453)	0.18	6.249 (0.396)	0.35
	Senior	100	23	27	29	21	1.600 (0.659)	0.13	-	-	-	-	-	-	-
France	U15	100	30	26	26	18	3.192 (0.363)	0.18	59	41	-	3.258 (0.071)	0.18	2.948 (0.400)	0.17
(July 2017)	U18	100	29	35	25	11	14.100 (0.003)*	0.38	33	35	32	0.139 (0.933)	0.04	11.533 (0.073)	0.34
	U21	100	33	21	28	18	5.521 (0.137)	0.24	29	33	38	1.218 (0.544)	0.11	5.198 (0.519)	0.23
	Senior	100	18	23	28	31	3.921 (0.270)	0.20	-	-	-	-	-	-	-
The Netherlands	U15	46	16	28	28	28	2.622 (0.454)	0.24	46	34	(20)	0.903 (0.342)	0.14	3.966 (0.265)	0.07
(July 2017)	U18	50	14	32	30	24	4.272 (0.234)	0.29	34	36	30	0.283 (0.868)	0.08	9.630 (0.141)	0.44
	U21	46	28	24	24	24	0.254 (0.968)	0.07	26	39	35	1.251 (0.535)	0.16	5.063 (0.536)	0.33
	Senior	50	26	26	30	18	1.522 (0.678)	0.17	-	-	-	-	-	-	-

Data for quartiles and years are percentage. Age-categories: U15: under 15, U18: under 18, U21: under 21 and senior ≥ 21. Q1: January–March, Q2: April–June, Q3: July–September, Q4: October–December. Y1: oldest cohort, Y2: second oldest cohort, Y3: youngest cohort (U15 officially includes only two cohorts). [#]The between-year effect is the constituent-year effect. *$p < 0.05$ indicating significance. [a]1 player who was one year younger. [b]6 players who were one year younger and 1 player who was two years younger.

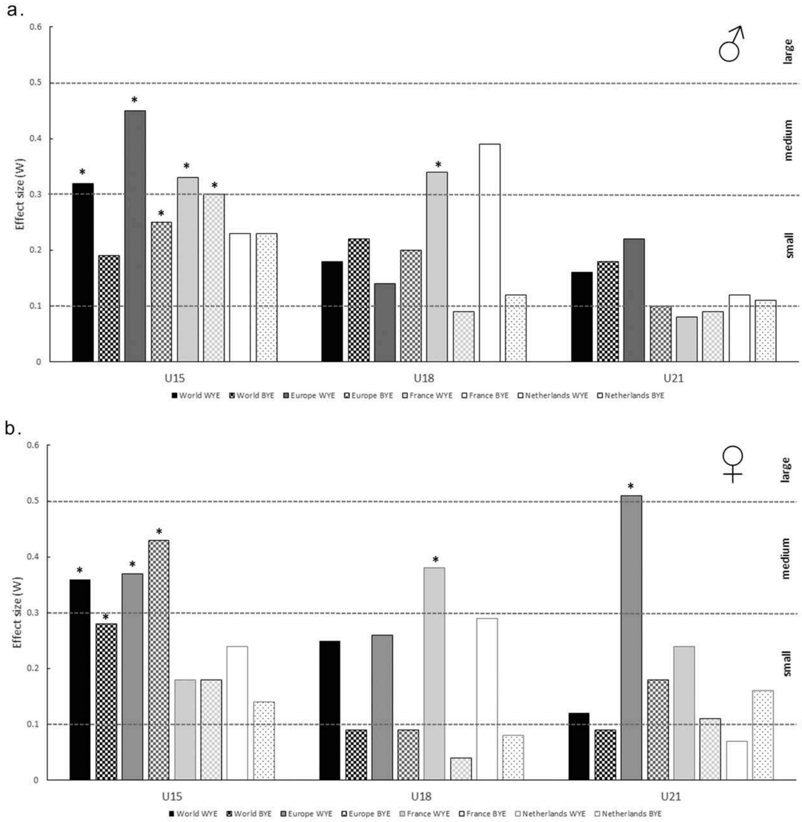

Figure 1. Effect sizes of the within-year effects and between-years effects in male (a) and female (b) players. WYE: within-year effect; BYW: between-year effect; *$P < 0.05$.

pronounced like in the more physical demanding sports. Another possible explanation might be related to the multiyear dynamic age category. In this case players of the youngest birth cohort in a certain age category will become the older cohort in the next year. This yearly change within an age category might prevent an interaction, especially when this is taken into account by the selection of players (Wattie et al., 2008). Additionally, when nations use different cut-off dates for their age categories than the international standard, an interaction effect might not be revealed in the international contexts although the competition level is considered stronger compared to the national contexts.

Even though no interaction effects were found, within-year effects and between-year effects were present for specifically the youngest players (U15) in the international contexts. This was in line with our hypotheses based on the previous studies in elite table tennis (Faber & Schorer, 2018; Liu et al., 2017), however, in contrast to the previous study in basketball (Steingröver et al., 2017). The within-year effect seems to be generally larger in table tennis than the between-year effect in the U15 group whereas this was the opposite in

German elite male basketball players U16. Although it was argued in the previous paragraph whether the maturation-selection argument (Smith et al., 2018) would hold in elite table tennis, it seems likely that RAEs are affected by this at least to a certain extent. To compete in the international context, players need to be selected by the national coaches to represent their countries. This means that only a small amount of players within a certain age category can be selected. When aiming for success (on short term), the well-developed or more mature players are more likely to select by the national coaches. At a young age (U15), maturity differences are more pronounced (Malina, Bouchard, Bar-Or, 2004), which might ensure temporary advantages for performance especially in a strong competition. Since the table tennis is an early entry sport (<10 years old) (Faber, Elferink-Gemser, Oosterveld, Twisk, Nijhuis-Van der Sanden, 2017) until the age of U15, the relative older players might benefit from their physical ability, psychological skills, intelligence, and experience when they compete with their same age peers (Musch & Grondin, 2001).

Evaluating the older age categories in the international context, only a trend of overrepresentation of the relatively older players was visible for the U18 players (within-year and between-year effects), whereas no effects could be recognized for U21 and senior players. There was one exception: a typical within-year effect was present in the U21 European female players. It is unclear why this effect is specifically present in this subsample. A possible explanation is that the subsample included only 51 players, who were specifically the better ones, instead of the intended top 100. It might be that within this subsample the competition level was really high and that the RAEs became more apparent. Another reasoning can be that specifically the female players born in the last quartile(s) quit from the sport or do not take part in the European matches anymore since the age > 18. At least it was possible to obtain a full sample of 100 players for U18. This could be related to the interaction of the players' performance results and the financial and supporting policies concerning the players in this age category in Europe. Often U21 players are grouped together with the senior players and need to share the funding or other support provided by national associations with the seniors. Likely, only those U21 female players that excel on international level will receive the support they need to continue their development. These might include specifically the relative older players as a result of the early benefits (Musch & Grondin, 2001).

As proposed, the national contexts seem to be less at risk for RAEs compared to the international ones. Only France revealed a significant within-year and between-year effect in U15 male players. And although we focused on the top 50 players of the Netherlands, only a trend could be recognized for the male Dutch subsamples U15 regarding the within-year and between-year effect. The lower competition level in the national contexts compared to the international context and the fact that players do not have to be selected to compete at the national level are suggested to be plausible explanations (Baker et al., 2009;

Schorer et al., 2015). These results actually point out another constraint that might influence the RAEs in table tennis as well; it seems to confirm our hypothesis that sex affects the appearance of the typical RAE at least in the U15 players in the national contexts. These results appear to be in line with earlier results from table tennis (Romann & Fuchslocher, 2014; Romann et al., 2018) and other ball sports (Delorme & Raspaud, 2009; Goldschmied, 2011) showing that RAEs seem to be more apparent in male players. As suggested in the introduction, this is probably related to the lower amount of female players in table tennis and (consequently) a lower level of competition (Cobley et al., 2009; Smith et al., 2018; Vincent & Glamser, 2006). Nonetheless, it needs to be acknowledges that the differences between sexes was not clearly visible in the other age groups and contexts.

Remarkably also significant within-year effects were shown in the French context for the U18 male and female players. This is too all probability due to the amount of competitive players and playing level in France in both sexes in this age category (Baker et al., 2009; Schorer et al., 2015). This is suggested to be related to both the population size in France, the popularity of table tennis (e.g. cultural importance) (Romann & Fuchlocher, 2014) and the available opportunities for the players to develop (Wattie et al., 2008). Moreover, the RAEs that appeared at an earlier stage (e.g. U15 or even earlier) might be conserved in the U18 category by the selection process for specific support (Wattie et al., 2015). If you are in the system once and already at an early age, you probably have better chances to maintain in the system (Steingröver et al., 2017).

Although this study adds new insights regarding the interaction and the main effects of the RAEs in sports, some limitations need to be acknowledged. The main limitation is that this study used a cross-sectional design. For that reason, it was not possible to have more insight in drop-outs and players entering the top 100 (or 50) at a later stage. A longitudinal design would give a deeper insight in the development of RAEs and their possible interaction over time. Another limitation is that it is unknown to what extent the official international cut-off dates for age categories and birth cohorts are used in competition and talent programs in countries all over the world. This might have affected the results of the study. A third limitation is the assumption of an equal birth distribution across all quartiles and cohorts (i.e. years). Using the birth statistics by month, sex and year of the corresponding population or a day corrected distribution would be more accurate and prevents a Type I error (Delorme & Champely, 2015). However, we checked for interactions between two factors with a multiway frequency analyses and an equal theoretical distribution is a prerequisite for this kind of analyses. In addition to this, actual birth statistics are not available for the international samples. Finally, it must be acknowledged that we did not analyze the RAEs with respect to performance results other that being ranked at the top 100 (or top 50). It could be that RAEs influence performance result to a higher extent than what is shown within this paper.

In conclusion, although no RAEs interactions were found, table tennis as an individual skill/technique based sport is at risk for within-year and between-year effect specifically in young players (U15) in the international context or national context with a high level of competition. Additionally, the RAEs seem to be more apparent in male players than in female players, which is probably due to differences within the environmental constraints. It is speculated that the existence of an RAE within a certain context will provoke or conserve RAEs at a later stage. The model as proposed by Wattie et al. (2015) including individual, task, and environmental constraints, the RAEs and the development over time seems to be useful to unravel the underlying mechanisms of the RAEs in sports. Future research should reveal the development of the RAEs over time in a longitudinal study while comparing more contexts/sports (Steingröver et al., 2017) and evaluate the association with the performance of players and other influencing constraints (e.g. handedness (Loffing, Schorer, & Cobley, 2010); cognitive growth and maturity (Wattie et al., 2008)) in a more comprehensive way. Additionally, studies focusing on new innovative approaches to eliminate RAEs (e.g. Mann & van Ginneken, 2017) are recommended (Wattie et al., 2008)

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ORCID

Irene R. Faber http://orcid.org/0000-0002-4994-0453
Jörg Schorer http://orcid.org/0000-0002-4888-7048

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