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RESEARCH

Darwinian selection for the fittest, oldest or youngest: relative age effects in European gymnastics

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Abstract

Purpose This study investigated relative age effects (RAEs) among artistic gymnasts participating in the last three European Championships.

Methods A total of 876 gymnasts (female; $n=396$, male; $n=480$) were included in this study. The chi-square ($\chi 2$) goodness-of-fit test was used to investigate birthdate distribution. Odds ratios and 95% confidence intervals were calculated for quartile comparisons. Poisson regression with canonical link was conducted to analyse count data. All the analysis was conducted separately for male and female gymnasts, as well as for each apparatus.

Results Considering the female gymnasts, Poisson regression was significant for all the sample ($R^2=0.07$; $p<0.05$) and apparatus (R^2 range = 0.05–0.08; $p<0.05$). The female gymnasts born at the beginning of the year were 0.64 more likely not to participate in the European Artistic Gymnastics Championships than those born at the end of the year. On the other hand, no such effect was determined for male gymnasts both in the total sample ($R^2=0.01$; $p>0.05$) and any of the apparatus (R^2 range = 0.00–0.01; all $p>0.05$). The study revealed a skewed birth date distribution in favour of relatively younger female gymnasts, while male gymnasts did not show this effect. Furthermore, in female gymnasts, this result was consistent across all apparatus, with gymnasts overrepresented in the last quarter.

Conclusion Such findings have been discussed with several moderators, hypotheses and models in this study. As a result, considering the consistent findings, particularly in female gymnastics, coaches and policymakers should reconsider RAEs to avoid talent loss and sports drop-out.

Keywords RAE · Talent identification and development · Athlete development · Birthdate · Selection bias

Abbreviations

RAEs Relative age effects
TID Talent identification and development

Introduction

The competitive nature of sports causes significant pressure on the talent identification and development (TID) process, which cultivates success-oriented practices by national and international authorities and governing bodies. These TID systems endeavour to develop "talented" athletes to elite standards [1]. In such systems, thousands of young athletes across sports engage in activities, and some are selected for well-resourced programmes [2]. Timing and management of this selection are highly important for TID systems. For instance, gymnasts typically begin training at the age of five or six [3], with initiation specialisation occurring even before the age of nine [4]. Although these practices, i.e., single sport participation at earlier ages and early specialisation, may prepare athletes for the demanding nature of elite sport [5, 6], they have also attracted significant criticism. In particular, TID practices are criticised for their low predictive value and lack of validity [1]. The idea that those who

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can "make it" can be called "talented" have been strongly criticised [7, 8]. Baker, et al. [8] expanded this discussion by recognising that these practices are based more on performance identification rather than talent identification. In line with this idea, Johnston and Baker [9] suggested that such selection decisions can be inaccurate, bias driven, and sometimes even illogical. Further to these discussions, for example, it has been observed that early success is not a prerequisite for success at the senior level in individual sports such as track and field and swimming. In fact, a large percentage of young successful athletes have a lower probability of excelling in junior and senior events [10–14]. Considered a cornerstone of such "biased" practices, relative age effects (RAEs) is a widely studied subject that may affect talent selection and identification [15].

RAEs are phenomena pointing out mainly the birthdate-biased distribution of athletes in individual and team sports resulting from age-grouping strategies to categorise youth athletes [16, 17]. This strategy is commonly used in sports settings to ensure equal participation, selection, and success opportunities for each athlete. However, it is highly insensitive to the subtle chronological age differences in the same age group and causes certain (dis)advantages. For instance, in annual age-group categories, it is possible to observe even 12 months difference between athletes born right after and before the cut-off date in the same calendar year. Hence, due to potential chronological differences, certain athletes may possess performance advantages depending on the sport's unique characteristics and demands. As a result, a birthdate asymmetry emerges within the age-grouped cohort, leading to an over- or under-representation of athletes based on their birthdate [2]. Consequently, some athletes are more likely to be selected and attain certain advantages such as better coaching, equipment, training, and experience opportunities [18–20].

From the earliest studies about RAEs, an increasing trend has been stated by Bilgiç and Işın [21] regarding the scientific production of RAEs. In this bibliometric analysis, the distribution of sports in RAEs research was presented, and it was observed that soccer emerged as the most popular sport, followed by ice hockey, basketball, handball and rugby. To explain RAEs, several hypotheses have been proposed and discussed in the literature [22–24]. As the most recent one, Wattie, et al. [24] proposed developmental systems model to explain all of the different results regarding RAEs in sports and based their model on Newell [25] constraints-based model. In the developmental systems model, a bidirectional interaction was suggested among individual, task and environmental constraints, and change over time was stated as another component to consider regarding the presence of RAEs. Considering the nature of most-researched sports [21], it can be asserted that they all emphasise strength- and endurance-related skills. On the other hand, studies on technique or aesthetic-related sports are quite limited and few compared to others, and some disagreements have been noted in aesthetic sports regarding the prevalence of RAEs.

In gymnastics, as a technique-related and aesthetic sports, Ste-Marie, et al. [26] stated a "flip-flop phenomenon" in female gymnasts with a biased distribution favouring late-borns. Similar findings in terms of overrepresentation of relatively younger gymnasts have been noted in the literature in Canadian over-15 years of age female gymnasts and male apparatus finalists in gymnastics in Olympic Games [27, 28]. In particular, "rotation or artistic" dominant tasks have been suggested as the underlying reason [29]. On the other hand, in figure skating—a sport highly dominated by rotational and artistic demands—Baker, et al. [30] reported no RAEs among Canadian figure skaters for both genders. On the contrary, Uğurlu and Bilgiç [31] reported that RAEs differed according to gender and discipline in figure skating. Specifically, significant RAEs appeared to favour early-born male skaters in the Singles and Pairs disciplines, while no such effect was noted in Ice Dance. In female skaters, no notable RAEs were observed either. van Rossum [32] determined no RAEs among dance students as well as Langham-Walsh, et al. [33] stated no "flipping" RAEs in elite female artistic gymnasts competing on the international platform. Yet, they stated that this finding depended on the task demands (i.e., apparatus). While there were no RAEs among gymnasts who competed in uneven bars and floor, significant RAEs were observed in favour of late-born gymnasts competing in the balance beam. Similarly, gymnasts in the vault neared significance too. Baker, et al. [30] also investigated RAEs in women's artistic gymnastics and determined an atypical distribution in favour of gymnasts in the second quartile, while the results were significant for the entire group and seniors but not for juniors.

Hereby, the findings on aesthetic sports, particularly in gymnastics, remain inconsistent, and further investigations are needed. This study aimed to investigate RAEs among gymnasts participating in the last three European Championships.

Methods

Participants

This study included male and female gymnasts who participated in the last three consecutive European Artistic Gymnastics Championships held in 2021, 2022, and 2023 to reach rather generalizable results of RAEs in gymnastics. A total of 876 gymnasts (264, 297 and 315, respectively) participated in the abovementioned championships (female; $n = 396$, age = 19.12 yr., male; $n = 480$, age = 23.89 yr.). At these championships, females and males competed on

different apparatus: four for females (i.e., vault, uneven bars, beam, and floor exercise) and six for males (i.e., floor exercise, pommel horse, parallel bars, vault, rings, high bar). Since gymnasts can compete on multiple apparatuses, these gymnasts were listed multiple times.

Design and procedure

The Akdeniz University Clinical Research Ethics Committee approved the study (ethical approval code:KAEK-317), which was conducted following the Declaration of Helsinki. Data on the date of birth, gender, and apparatus of all gymnasts participating in the championships were obtained from the official website of European Gymnastics (https://www.europeangymnastics.com/). To evaluate RAEs, the birth months were divided into four quarters. Since the cut-off date for the European Championships is January 1st, gymnasts born in January, February, and March were grouped in Q1; gymnasts born in April, May, and June were grouped in Q2, gymnasts born in July, August, and September were grouped in Q3 and gymnasts born in October, November, and December were grouped in Q4.

Data analysis

Chi-square ($\chi 2$) goodness-of-fit tests were used for observed and theoretically expected differences between the distribution of birth dates. Theoretically, birth rates were assumed to be equal in all quarters (i.e., 25% for each quartile). Cramér's V was used for effect size, with trivial, small, medium, and large effects being "$0.06 \leq V$", "$V = 0.06$–0.17", "$V = 0.18$–0.29", and "$V \geq 0.30$", respectively, as interpreted according to Cramér [34]. For the comparisons (i.e., "Q1 vs. Q4") odds ratios (ORs) and 95% confidence intervals (CI) were calculated. Additionally, the birthdate distribution was treated as a continuous variable to further investigate RAEs and increase statistical power by reducing the number of comparisons. Thus, Poisson regression with canonical link was conducted to analyse count data using the formula $y = e^{(b0+b1x)}$. The y term represents the frequency of birth in a given week, and the x term is the explanatory variable (i.e., the time of birth). Time of birth, ranging between 0 and 1, was calculated considering the formula TB = (WB − 0.5)/52. WB represents the athletes' birth week (e.g., in players born between the 1st and 7th January WB, it was 1). The relative odds (i.e., index of discrimination, ID) of being selected for a player born in the first week compared to the last week of the competition year and R^2 value were indirectly calculated from the equation according to previous studies [35, 36]. All the analysis was conducted separately for male and female gymnasts, as well as for each apparatus. All data were analysed with custom-written software in MATLAB R2023a (MathWorks, Natick, Massachusetts).

Results

Figure 1 shows the birth quartile distribution of female and male gymnasts according to all sample and separately for each apparatus. An asymmetry was determined in the distribution of birth quarters of female gymnasts ($\chi^2 = 9.919$, $p = 0.019$, $V = 0.09$). More gymnasts were born in the last quarter compared to their counterparts born in the first quarter (OR = 0.7, CI = 0.47–1.06). Similarly, the birth quarter distribution of female gymnasts who competed in all the apparatuses was not equally distributed (vaults; $\chi^2 = 9.855$, $p = 0.02$, $V = 0.1$, floor exercise; $\chi^2 = 10.134$, $p = 0.017$, $V = 0.1$, uneven bars; $\chi^2 = 8.988$, $p = 0.029$, $V = 0.1$, and balance beam; $\chi^2 = 11.459$, $p = 0.009$, $V = 0.11$). According to the above findings, quartile comparison odds ratios results indicate a trend of a higher likelihood of gymnasts being born in the last quarter than in the first quarter across all apparatus (i.e., vaults; OR = 0.65, CI = 0.42–1.02, floor exercise; OR = 0.69, CI = 0.44–1.09, uneven bars; OR = 0.72, CI = 0.46–1.12, and balance beam; OR = 0.67, CI = 0.43–1.05). For more details, see Fig. 1.

In male, the analysis is asymmetric, with a small effect size, in the birth quarter distribution ($\chi^2 = 8.317$, $p = 0.04$, $V = 0.08$). In particular, the data showed a higher percentage of gymnasts born in third and last quarter compared to the first two. Nevertheless, the odds ratio comparison revealed only a tendency (not statistically significant) indicating a slightly higher likelihood of being selected in Q4 than in Q1 (OR = 0.94, CI = 0.66–1.35). When considering the apparatus separately, analysis detected an even quartile distribution compared to the expected distribution (vault; $\chi^2 = 2.63$, $p = 0.452$, $V = 0.05$, floor exercise; $\chi^2 = 2.188$, $p = 0.534$, $V = 0.05$, pommel horse; $\chi^2 = 5.011$, $p = 0.171$, $V = 0.07$, rings; $\chi^2 = 4.25$, $p = 0.236$, $V = 0.06$, parallel bars; $\chi^2 = 2.79$, $p = 0.425$, ES = 0.05 and horizontal bar ($\chi^2 = 6.476$, $p = 0.091$, $V = 0.08$). According to this analysis, the odds ratio comparison revealed no significant difference between Q4 versus Q1 (vault; OR = 0.91, CI = 0.59–1.4, floor exercise; OR = 0.97, CI = 0.63–1.47, pommel horse; OR = 0.93, CI = 0.61–1.42, rings; OR = 0.98, CI = 0.63–1.5, and parallel bars; OR = 0.94, CI = 0.6–1.46; Horizontal Bar (OR: 1.09, CI: 0.71–1.69) (Fig. 1).

Figure 2 shows scatter plots for the frequency of RAEs according to the week of birth for each apparatus in female and male gymnasts. The results of the Poisson regression analysis of RAEs in female and male gymnasts are presented in Table 1. When analysing female gymnasts, Poisson regression was significant for all the sample. The ID highlighted that the gymnasts born near the start of the year were 0.64 more likely to not participate in

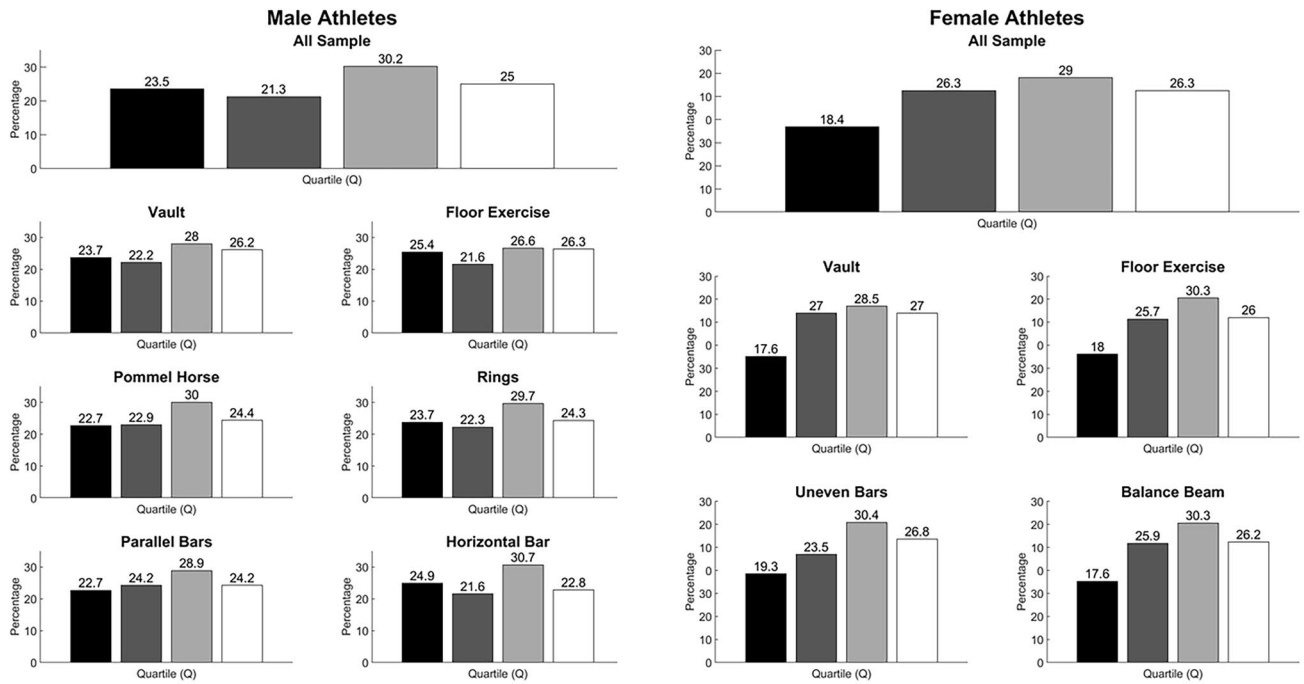

Fig. 1 Birthdate distribution of female and male gymnasts competing in the European Artistic Gymnastics Championships. Data are presented for the all sample and according to the competed apparatus

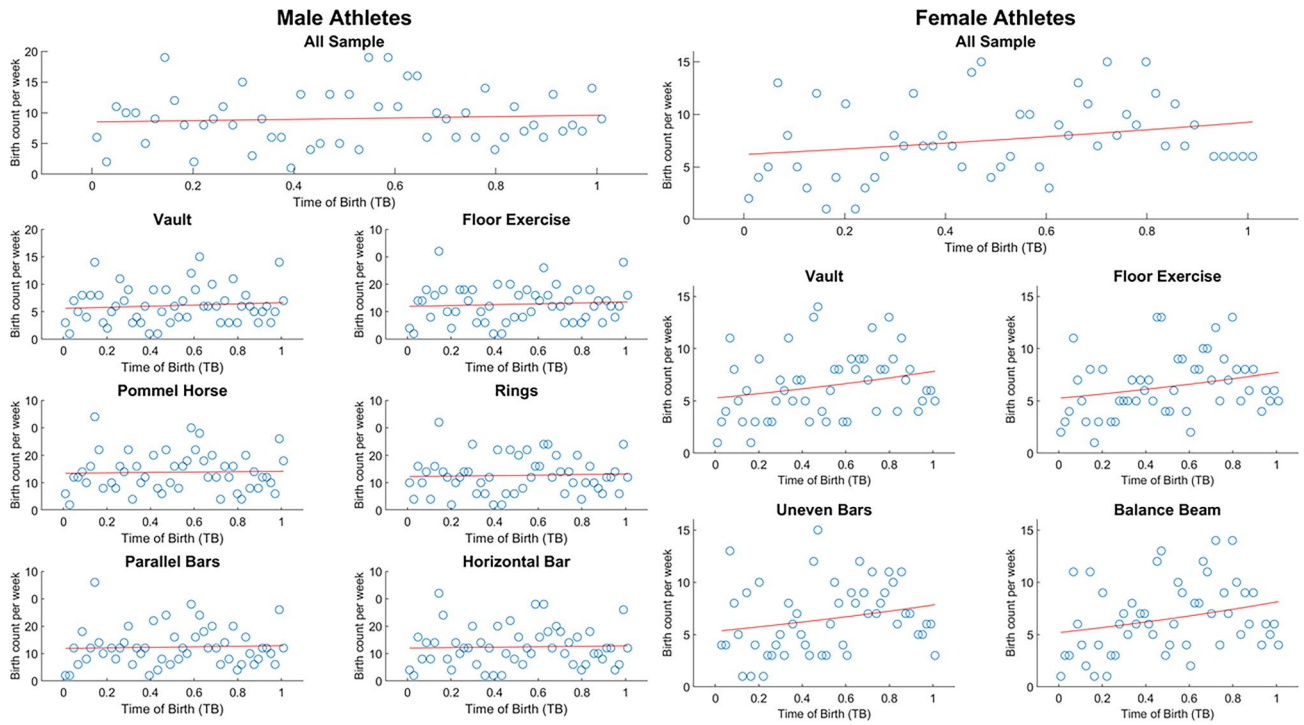

Fig. 2 Scatter-plots of relative birth frequency by week considering all female and male gymnasts and the different apparatus. The red line represents the best fit of the Poisson regression modelling

Table 1 Poisson regression analysis of RAEs in female and male gymnasts

Category		N	W_B	T_B	b_0	b_1	ID	R^2	p
Female	All sample	396	28.58 ± 14.27	0.54 ± 0.27	1.80	0.45	0.64	0.07	0.01
	Vault	330	28.80 ± 14.24	0.54 ± 0.27	1.64	0.43	0.65	0.07	0.02
	Floor exercise	327	28.77 ± 14.19	0.54 ± 0.27	1.63	0.43	0.65	0.08	0.02
	Uneven bars	332	28.89 ± 14.28	0.55 ± 0.27	1.65	0.42	0.66	0.05	0.03
	Balance beam	340	28.86 ± 14.00	0.55 ± 0.27	1.61	0.51	0.60	0.08	0.01
Male	All sample	480	27.57 ± 14.96	0.52 ± 0.29	2.14	0.13	0.88	0.01	0.42
	Vault	325	27.78 ± 15.15	0.52 ± 0.29	1.72	0.17	0.84	0.01	0.36
	Floor exercise	338	27.56 ± 15.41	0.52 ± 0.30	1.79	0.12	0.88	0.01	0.50
	Pommel horse	353	27.69 ± 14.81	0.52 ± 0.28	1.91	0.06	0.95	0.00	0.76
	Rings	337	27.37 ± 14.96	0.52 ± 0.29	1.81	0.08	0.92	0.00	0.66
	Parallel bars	322	27.70 ± 14.68	0.52 ± 0.28	1.78	0.09	0.92	0.00	0.65
	Horizontal bar	329	27.32 ± 14.80	0.52 ± 0.28	1.79	0.07	0.93	0.00	0.70

W_B week of birth, T_B time of birth, b_0 intercept term of the exponential model, b_1 coefficient associated with the predictor variable, *ID* index of discrimination

the European Artistic Gymnastics Championships than those born at the end of the year. In addition, the Poisson regression showed a significant effect for all considered apparatus (for vault: $p = 0.02$; $R^2 = 0.07$); for floor exercise: $p = 0.02$; $R^2 = 0.08$; for uneven bars: $p = 0.03$; $R^2 = 0.05$; and for balance beam: $p = 0.01$; $R^2 = 0.08$). The IDs analysis showed that athletes born in the first week after the selection date had less likely to be included in the European Artistic Gymnastics Championships than those born in the last week (ID range from 0.60 to 0.65). On the other hand, the Poisson regressions were not significant for male gymnasts in any of the apparatus (all $p > 0.05$; R^2 range = 0.00–0.01).

Discussion

This study aimed to investigate RAEs among elite gymnasts participating in the last three European Championships. The key findings of the study were that (a) overall, in European female gymnasts Championships, data revealed a skewed birthdate distribution favouring relatively younger gymnasts (Q1 = 18.4% vs Q4 = 26.3%), (b) this effect was consistent in all apparatus considered (i.e., bars, beam, floor and vault) and (c) no such effect was determined in male gymnasts. Overall, the present findings partially align with RAEs literature on gymnastics. Data suggested that European female gymnasts Championships were affected by a reversal RAEs, whereas in male, a more homogeneous birth distribution was observed. Specifically, in females, RAEs were evident across all disciplines considered, although with a small effect size. On the other hand, when comparing Q1 versus Q4 birth distributions, no significant differences were observed, even though there was a tendency in favor of Q4 athletes. This effect is evident across all disciplines.

Wattie et al.'s [24] model may help to explain these results better. From this model's perspective individual, task and environmental constraints, and the interaction among them play a foundational role in the presence of RAEs. Regarding the individual constraints, "accumulative advantage" [19, 37] is one of the concepts discussed in RAEs literature. It denotes the (dis)advantage an athlete attains in several contexts such as selection and reselection patterns. In other words, in female competitions, we can hypothesize that, over time, this may lead to a residual bias, referred to as the so-called knock-on effect, whereby the overrepresentation of relatively younger players at senior levels becomes apparent [38, 39]. As a task constraint, gymnastics is a sport that highly emphasises artistic and rotational tasks. Related to such concepts, Moeskops et al. [40] discussed the tendency of coaches to select relatively younger gymnasts and those genetically predetermined to have shorter and slighter statures, especially in female gymnastics [41] also discussed the selection of preferably short, normal or late-maturing gymnasts. Thus, delayed maturation might be an important point to consider as it is a potential characteristic of higher skilled gymnasts and a performance advantage in gymnastics [33, 42]. So, the demands and characteristics of the task are a strong determiners while pronouncing RAEs. Considering all these results, in RAEs literature, Ste-Marie, et al. [26] pronounced a "flip-flop phenomenon" as an overrepresentation of relatively younger gymnasts. This proposal was supported by several other research in gymnastics, such as Hancock, et al. [27] and Yoon and Park [43]. For instance, Yoon and Park [43] determined that the frequency of athletes born in Q1 was the lowest, while gymnasts born in Q4 showed the highest frequency in elementary and middle-high school gymnasts. These abovementioned features may align with gymnastics demands such as artistry, flexibility and elastic strength/power regarding several technical skills

such as jumps, splits, cartwheels and saltoes. Furthermore, selecting younger gymnasts may also contribute to "accumulative advantage" [19, 37], which is one of the environmental constraints explained in Wattie et al.'s model [24], causing RAEs in sports. Our findings might be considered from that perspective, considering that our sample comprises senior gymnasts. As discussed above, the advantages of being relatively younger might continue to accumulate throughout gymnasts' careers.

Furthermore, our findings in females also support the underdog hypothesis, which was first suggested by Krogman [44] in baseball. According to that, relatively younger athletes might be more successful at the adult level as they experience more challenges compared to early-born, which may enhance their psychological, technical and tactical skills developments that are quite critical to succeed at such levels [22, 45]. Moreover, given the same RAEs trend similar to studies on younger gymnastic athletes, our data linked with a more substantiated knock-on effect in this female context [46].

It is rather important to develop a strong technical foundation, regardless of their physical attributes, which seems to be the case in this study, considering that the sample included elite senior gymnasts who represented their countries at such a high level. Thus, it can be speculated and suggested that late-born female gymnasts might tend to be more successful. On the contrary, inconsistent overall asymmetries in relative age were observed when focused on male athletes. Nevertheless, data suggested a tendency to favour relativity younger athletes, but the effect is not significant. On the other hand, in other studies conducted with senior gymnasts, different results have been reported. For instance, Kalinski, et al. [28] determined different results based on different parameters such as gender, all-around qualifiers (AAQ) and apparatus finalists (AF). In that study, statistically significant bias was noted in favour of relatively younger male gymnasts in AF, but no other significance was reported. Another study by Kalinski, et al. [47] indicated that the highest number of male gymnasts were born in January (13%) compared to other months in All-Around Finals and in Event Finals at all Olympic Games held from 1980 to 2016. This asymmetry was not statistically significant, though. In our study, the findings revealed no RAEs among male gymnasts, which aligns with such results. Furthermore, Baker, et al. [30] reported a significant overrepresentation of female gymnasts born in the second quartile of the year, which is a quite different result. Considering all of these contradictory findings, further studies are needed. In particular, designing longitudinal research could be helpful to see the whole picture and test Wattie et al.'s [24] model.

This research has some limitations that future research should consider. This research focused on the last three European Championships in Artistic Gymnastics. Thus, gymnasts may have participated in more than one championship. Furthermore, as gymnasts have the right to compete in more than one apparatus in each championship, they might be included in the study more than once while analysing gymnasts in each apparatus separately. Additionally this is a cross-sectional study. Thus, it is not possible to monitor the long-term development of athletes and determinate the rate of drop-out and success. In this case, it calls for further investigation as capturing gymnasts' career trajectories to understand better how age group strategies and cut-off dates affect gymnasts' sporting careers and senior opportunities.

Practical implications and future directions

In gymnastics, a limited number of studies on RAEs has been conducted in different contexts such as female gymnasts in Canada [27, 30], gymnasts in Olympic games [28, 47] and female gymnasts in World championships [33]. All of them have several limitations such as focusing on only males or females, and date of data included in those studies. Especially the ones including data before 2006 have limited implications considering the change of scoring system to an open-ended system from "perfect 10" scoring system. Our study fills this literature gap, particularly due to its ecological validity, allowing for practical implications. The study highlights the potential impact of RAEs in the selection process at the elite level of gymnastics, particularly among female gymnasts. For this reason, coaches and talent scouts, especially for female gymnasts, should consider this aspect when selecting gymnasts in order to ensure fair evaluation without any bias related to their birthdates. Again, policymakers and governing bodies should aim to limit possible asymmetries in terms of birthdate through targeted actions in female context. This could include implementing quotas, creating development pathways for relatively older gymnasts, or offering more frequent selection opportunities throughout the year. Nevertheless, considering the contradictory results, further research is needed to thoroughly understand the phenomena and to develop strategies to prevent talent loss or early drop-out from sports. Moreover, given the limited studies in the literature on this specific sport, future research should investigate the potential mechanisms driving RAEs, focusing, for example, on possible psychological (e.g., motivation, self-confidence, and perceived competence) and social moderators (e.g., peer relationships and coach attitudes).

In conclusion, results suggested that in European gymnastics, RAEs are modulated by gender. Significant RAEs were found in female gymnasts, while no such bias was noted in males. In particular, a distribution bias favoured relatively younger female gymnasts compared to their older counterparts. This study also investigated apparatus specialisation

with a more sophisticated and detailed appreciation of RAEs. However, no significant differences were found.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

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