

Original research manuscript

Relative Age Effect in Team and Individual Sports: A Systematic Review with Quantitative Synthesis

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Abstract: The Relative Age Effect (RAE) influences talent identification and athlete development across sports. This study presents a systematic review with a secondary quantitative synthesis of extracted or calculated odds ratios (ORs) to examine the magnitude and variability of RAE in selected team sports (football, ice hockey, basketball) and individual sports (tennis, swimming, gymnastics). A total of 91 peer-reviewed studies comprising 158 samples and more than 40,000 athletes aged 8–18 years were included. ORs were defined as the likelihood of being relatively older versus relatively younger within an age cohort and were extracted when reported or calculated from birthdate frequency distributions using comparisons between the earliest and latest birth quartiles. Team sports showed a consistent, moderate RAE (mean ORs approximately 1.28–1.32), whereas individual sports demonstrated greater variability, with gymnastics showing the strongest effect (mean OR = 2.10) and swimming the weakest (mean OR = 1.20). Exploratory comparisons suggested differences in the distribution of ORs between team and individual sports. Overall, these findings indicate that RAE is not uniform across sport contexts but is shaped by sport-specific demands and selection practices. Practical strategies such as bio-banding, flexible competition formats, and increased awareness among coaches and administrators may help mitigate selection bias and support more equitable developmental pathways.

Keywords: team sports; individual sports; talent identification; youth sport; athletic development.

1. Introduction

The Relative Age Effect (RAE) is a well-documented phenomenon that significantly influences talent selection, athlete development, and long-term success in sport. This effect manifests as an uneven distribution of athletes born in different parts

of the calendar year within age-categorized sports, with those born in the early months of the year often having advantages in physical, psychological, and social maturity (Cobley et al., 2009; Musch & Grondin, 2001). While RAE is evident across a variety of sports, its



intensity varies depending on the sport's nature and its supporting organizational structures (Altimari et al., 2018; Lagestad et al., 2018).

RAE primarily stems from differences in biological maturation among athletes within the same age category. Older athletes in a given age group benefit from more advanced physical development, reflected in superior results in speed, strength, and agility tests (Koloničný et al., 2018). These advantages are often reinforced by psychosocial factors, such as higher expectations from coaches and better training conditions provided to older athletes (Beals et al., 2018; Haycraft et al., 2018). One illustrative example is the "Pygmalion effect," where coaches focus more attention on athletes who exhibit superior physical attributes, further supporting their development (Sierra-Díaz et al., 2017; Sweeney et al., 2023). Hancock, Adler, and Côté (2013) further identify the Matthew and Galatea effects. The Matthew effect—"advantages for some but not for others"—explains how early parental involvement in sport can provide certain children with important early skill development. The Galatea effect describes how expectations imposed on an individual often lead to behaviors aligned with those expectations, with athletes raising their self-expectations and continuing to succeed.

Most contemporary studies on RAE focus on football (Arslan et al., 2020; Götze & Hoppe, 2020; Li et al., 2020; Roberts et al., 2020) and ice hockey (Bezuglov et al., 2020; Lemoyne et al., 2021; Nykodým et al., 2020), the most popular team sports. However, numerous studies also examine RAE in individual sports, such as tennis (Moreira et al., 2017; Ulbricht et al., 2015; Wendling &

Mills, 2018) or skiing (Bjerke et al., 2020; Müller et al., 2017; Steidl-Müller et al., 2019). Researchers also address less mainstream sports such as taekwondo (Albuquerque et al., 2012), judo (Albuquerque et al., 2015), boxing (Edginton et al., 2014), ski jumping (Baker et al., 2010), chess (Breznik & Law, 2016), rugby (Cobley & Till, 2017), and shooting sports (Delorme et al., 2009). Most of these studies found a significantly higher proportion of athletes born in the first and second quarters of the year, with RAE being more pronounced in junior categories.

In team sports such as football, basketball, and ice hockey, RAE is most prominent. This is primarily due to structural demands for immediate physical readiness and performance, which lead to a preference for relatively older athletes in elite team selection (Fumarco & Rossi, 2018; Silva et al., 2015). For example, Fumarco & Rossi (2018) reported that over 60% of players in elite football academies were born in the first quarter of the year. This imbalance can negatively impact younger players, who are often excluded despite long-term potential (Figueiredo et al., 2020). In contrast, individual sports show more variable RAE patterns. For instance, in gymnastics, younger athletes benefit from lower body weight and greater flexibility, while in swimming, RAE is less pronounced due to the emphasis on technical and endurance skills (Ulbricht et al., 2015). Additionally, a study by Bilgiç and Devrilmez (2021) found that RAE intensity decreases with athlete age in badminton, thanks to more flexible competition structures.

RAE also varies across regions and cultures. For example, European countries with centralized sports systems, such as

Spain, show stronger RAE than Scandinavian countries that emphasize inclusivity (García-Rubio et al., 2022; Rađa et al., 2018). These differences highlight the importance of organizational structures and competition rules in shaping RAE.

RAE affects not only talent selection but also long-term success in sport. Younger athletes face greater barriers to entering elite sporting structures, increasing the risk of early dropout. Some studies suggest, however, that athletes who overcome initial disadvantages may exhibit greater resilience and long-term success (Bjørndal et al., 2018). This effect can be partially mitigated through the implementation of bio-banding methods, which replace chronological age categories with those based on biological maturation (Malina et al., 2004).

This study aims to compare the intensity and variability of RAE in team sports (football, basketball, ice hockey) and individual sports (tennis, swimming, gymnastics). The findings may contribute to the development of fairer and more effective sports structures and provide concrete recommendations for coaches and competition organizers.

2. Materials and Methods

Sample size estimation and justification

As this systematic review with a secondary quantitative synthesis synthesized data from previously published studies, a priori sample size estimation was not applicable. Instead, the study included a comprehensive synthesis of data from 91 peer-reviewed studies covering 158 research samples and over 40,000 athletes, which provides sufficient statistical power to address the research questions. Of these, 66

samples focused on team sports (25 in football, 20 in ice hockey, and 21 in basketball), while 92 samples dealt with individual sports (30 in tennis, 32 in swimming, and 30 in gymnastics). The selection of studies from which these samples were drawn followed predefined criteria: studies had to address either team or individual sports in which RAE is well-documented in the literature; they had to include youth, junior, or senior age categories with clearly defined age groups; and originate from various regions to enhance generalizability. Only peer-reviewed studies were included. The data were categorized into team and individual sports and processed with attention to variability in RAE prevalence.

Procedures

This study was conducted as a systematic review with a secondary quantitative synthesis. The literature search was performed in the PubMed, Scopus, and Web of Science databases and covered studies published up to December 2024. The search strategy combined terms related to the Relative Age Effect (e.g., “Relative Age Effect”, “RAE”) with terms describing sport context (e.g., “team sports”, “individual sports”) and the names of specific sports (e.g., “football”, “ice hockey”, “basketball”, “tennis”, “swimming”, “gymnastics”).

Titles and abstracts were screened to identify potentially relevant studies, and full texts of eligible articles were subsequently assessed against predefined inclusion and exclusion criteria. Duplicate records were removed prior to screening. The study selection process followed the PRISMA guidelines and

consisted of the phases of identification, screening, eligibility assessment, and inclusion. The database search initially identified 482 records; after removal of duplicates ($n = 61$), 421 records were screened at the title and abstract level, 134 full-text articles were assessed for eligibility, and 91 studies comprising 158 independent samples were included in the final quantitative synthesis (see Figure S2 in Supplementary Materials).

Eligibility criteria

Studies were included if they (a) examined the relative age effect (RAE) in youth, junior, or senior athletes within clearly defined age categories; (b) reported birthdate distributions or provided data enabling the calculation of odds ratios; and (c) were published as peer-reviewed journal articles. Studies were excluded if they (a) were not peer-reviewed, (b) did not provide sufficient quantitative information, or (c) focused exclusively on adult populations without age-group differentiation. Although some primary studies used the term “senior”, only samples with clearly defined youth or junior age categories within the 8–18-year range were retained for the present synthesis.

Data extraction

Data were extracted independently by the author using a standardized form. Extracted variables included sample size, age category, sport discipline, and effect size (odds ratio). In cases where data presentation was unclear, calculations were based on available frequency distributions of birthdates.

Calculation of odds ratios

Odds ratios (ORs) were defined as the likelihood of being relatively older versus relatively younger within an age cohort. When primary studies reported ORs directly, these values were extracted. When ORs were not reported, they were calculated from available birthdate frequency distributions using comparisons between the earliest and latest birth quartiles, in line with established RAE methodology. Due to heterogeneity in reporting across studies, ORs were treated as relative indicators rather than standardized population-level estimates.

Quality assessment

The methodological quality of the included studies was assessed using three predefined criteria: (1) clarity of sample description, (2) completeness of reported birthdate data, and (3) appropriateness of statistical methods used to analyze the RAE. Each study was evaluated against these criteria to determine whether it provided sufficient information for inclusion in the quantitative synthesis. Studies that failed to meet these minimum quality requirements—most commonly due to incomplete birthdate reporting or insufficient methodological detail—were excluded during the screening process. The majority of included studies demonstrated adequate methodological quality for the purposes of descriptive and exploratory quantitative comparison. Given the exploratory nature of the synthesis, no weighting based on study quality was applied. No studies were excluded solely on the basis of quality once quantitative eligibility criteria were met.

Statistical Analysis

The quantitative component of this review represents a secondary and exploratory analysis of odds ratios (ORs) extracted or calculated from the included studies, rather than a formal meta-analytic model. Odds ratios were interpreted as indicators of the relative likelihood of being relatively older versus younger within a given sport context, rather than as direct estimates of population-level prevalence. The primary aim of this quantitative synthesis was to compare the distribution and variability of reported RAE effects across sports and sport categories, rather than to estimate pooled population-level effects. Consequently, effect sizes were analyzed descriptively and comparatively, without variance-based weighting or explicit modelling of between-study heterogeneity. The results of inferential statistical tests should therefore be interpreted as exploratory rather than confirmatory.

A combination of descriptive and exploratory inferential statistical methods was used to evaluate the data. For each sport discipline, mean values, standard deviations, medians, minimum, and maximum odds ratios (OR) were calculated. Given the exploratory nature of the synthesis and the heterogeneity of included samples, confidence intervals for mean OR values were not calculated, as they may provide a misleading impression of precision.

To compare mean OR values between team and individual sports, an independent

samples t-test (Welch's variant) was applied. Differences among individual sports were assessed using one-way analysis of variance (ANOVA), followed by a series of Welch's t-tests for pairwise comparisons, due to violations of the assumption of homogeneity of variances.

The assumptions of normality and homogeneity of variances were assessed using the Shapiro–Wilk test and Levene's test, respectively. Statistical significance was set at a level of $p < 0.05$. Effect size for the comparison between sport categories was calculated using Cohen's d . Given the exploratory nature of the quantitative synthesis, no adjustments for multiple comparisons were applied, and p -values should be interpreted accordingly. All statistical analyses were performed using IBM SPSS Statistics (version 29.0).

3. Results

Prior to the application of parametric statistical tests, the assumption of normal distribution of OR values within each sport category was assessed using the Shapiro–Wilk test. This test is considered robust and suitable for smaller sample sizes. As shown in Table 1, the p -values for all six sports exceeded the threshold of statistical significance ($p > 0.05$), indicating that the null hypothesis of normality could not be rejected. These results support the validity of using parametric methods such as t-tests and ANOVA for subsequent analyses.

Table 1. Shapiro–Wilk Test of Normality

Sport	Shapiro-Wilk W	p-value (normality)	Normality
Football	0.975	0.687	Yes
Ice Hockey	0.984	0.913	Yes
Basketball	0.963	0.365	Yes
Tennis	0.949	0.157	Yes
Swimming	0.956	0.248	Yes
Gymnastics	0.957	0.253	Yes

Note: W = Shapiro–Wilk test statistic; p-value < 0.05 indicates violation of the normality assumption.

To determine whether the variance in OR values was equal across groups, Levene’s test for homogeneity of variances was conducted. This test assesses whether the variability in a dependent variable is similar across categories of an independent variable. The result ($F = 11.012$, $p < 0.001$) indicates a statistically significant difference in variance,

suggesting that the assumption of homogeneity was violated. However, as the inferential analysis employed Welch’s t-test, which is robust to variance heterogeneity, the validity of the results remains unaffected. Table 2 presents the detailed outcome of this test.

Table 2. Levene’s Test of Homogeneity of Variances

Test	F-value	p-value	Homogeneity of variances
Levene's test	11.012	$p < 0.001$	No

Note: F = Levene’s test statistic; p-value < 0.05 indicates a significant difference in group variances (i.e., violation of homogeneity assumption).

Descriptive statistics for the Odds Ratio (OR), representing the magnitude of the RAE, are presented in Table 3. Among team sports, the OR values were relatively consistent, with football ($M = 1.32$), ice hockey ($M = 1.29$), and basketball ($M = 1.28$) all showing moderate RAE with low standard deviations ($SD = 0.35$ – 0.42). In contrast, individual sports

demonstrated a broader spectrum. Tennis ($M = 1.45$, $SD = 0.61$) showed a moderately strong RAE, swimming ($M = 1.20$, $SD = 0.48$) showed the weakest effect, and gymnastics exhibited the highest OR ($M = 2.10$, $SD = 1.25$), pointing to a particularly strong and variable RAE. These variations justify further inferential examination.

Table 3. Descriptive Statistics of OR by Sport

Sport	Category	Mean OR	SD	Median OR	Min OR	Max OR
Football	Team	1.32	0.35	1.25	0.5	2.5
Ice Hockey	Team	1.29	0.41	1.15	0.6	2.0
Basketball	Team	1.28	0.42	1.2	0.11	2.78
Tennis	Individual	1.45	0.61	1.38	0.5	3.0
Swimming	Individual	1.2	0.48	1.1	0.8	2.0
Gymnastics	Individual	2.1	1.25	1.9	1.0	5.0

Note: OR = Odds Ratio indicating the relative likelihood of the Relative Age Effect (RAE). SD = Standard Deviation; Min = Minimum value; Max = Maximum value. Higher OR values suggest stronger RAE presence.

To further investigate sport-specific differences in RAE, post-hoc pairwise comparisons were performed using Welch's t-test, suitable for data with unequal variances and sample sizes. It should be noted that the reported p-values are unadjusted for multiple comparisons and should therefore be interpreted with caution. The most notable difference was observed between football and gymnastics ($t = -5.34$, $p < .001$), with a large effect size (Cohen's $d = -1.38$). Moderate to large effects were also

observed in comparisons between other team and individual sports, including football vs. tennis and gymnastics vs. swimming. Although not all differences reached statistical significance, the consistent trend supports the notion that RAE is more prevalent and variable in individual sports. Table 4 summarizes all comparisons and corresponding effect sizes, which provide practical insight into the extent of differences beyond mere statistical significance.

Table 4. Post-hoc Comparisons and Effect Sizes

Comparison	t	p-value	Cohen's d
Football vs. Ice Hockey	0.15	0.879	0.04
Football vs. Basketball	-0.33	0.7443	-0.08
Football vs. Tennis	-1.58	0.1218	-0.41
Football vs. Swimming	0.94	0.3541	0.24
Football vs. Gymnastics	-5.34	$p < 0.001$	-1.38
Ice Hockey vs. Basketball	-0.44	0.6637	-0.11
Ice Hockey vs. Tennis	-1.61	0.1145	-0.41
Ice Hockey vs. Swimming	0.76	0.4529	0.2
Ice Hockey vs. Gymnastics	-5.32	$p < 0.001$	-1.37
Basketball vs. Tennis	-1.2	0.2345	-0.31
Basketball vs. Swimming	1.11	0.2703	0.29
Basketball vs. Gymnastics	-5.07	$p < 0.001$	-1.31
Tennis vs. Swimming	2.09	0.0407	0.54
Tennis vs. Gymnastics	-4.23	0.0001	-1.09
Swimming vs. Gymnastics	-5.53	$p < 0.001$	-1.43

Note: Welch's t-test was used due to unequal variances. Cohen's d = standardized effect size; values of 0.2, 0.5, and 0.8 are interpreted as small, medium, and large effects, respectively. P-values are unadjusted for multiple comparisons.

4. Discussion

This study investigated the RAE in team and individual sports, aiming to examine its prevalence and variability across six disciplines. Based on a systematic review with a secondary quantitative synthesis of 158 samples involving over 40,000 athletes aged 8–18, team sports demonstrated a consistent but moderate RAE (mean OR = 1.29–1.32), whereas individual sports

showed higher variability, with gymnastics exhibiting the most pronounced effect (mean OR = 2.10) and swimming the lowest (mean OR = 1.20). These differences were supported by exploratory statistical comparisons, suggesting greater variability of RAE in individual sports compared to team sports ($t = -2.97$; $p = 0.0036$; Cohen's $d = 0.43$). Furthermore, a one-way ANOVA confirmed

significant differences among the six sport disciplines ($F(5, 152) = 6.92$; $p < 0.001$), with post-hoc testing revealing a particularly strong contrast between gymnastics and basketball ($p = 0.0009$).

These findings align with previous studies (e.g., Romann & Fuchslocher, 2013; Smith et al., 2018), suggesting that selection pressures, competition structures, and sport-specific developmental pathways contribute to the varying impact of RAE. Team sports, such as football, ice hockey, and basketball, often involve early selection based on physical readiness, which may explain their consistent RAE patterns. In contrast, individual sports, particularly gymnastics, emphasize early specialization and biological maturity, which may exacerbate the RAE.

The variability observed in individual sports supports the hypothesis that structural and contextual features of each discipline strongly influence RAE magnitude. While gymnastics showed the highest prevalence of RAE, swimming demonstrated minimal effect, potentially due to its focus on technical development and greater inclusivity at youth levels.

Several mechanisms underlie the RAE, including biological maturation, which gives relatively older children an advantage in strength, coordination, and speed during key developmental stages (Malina et al., 2004). Social reinforcement—such as parental and coach expectations—and structural factors—such as rigid age-grouping systems—further amplify this effect (Hancock et al., 2013; Smith et al., 2018). In particular, countries with flexible age categories and selection practices, such as those in Scandinavia, have shown reduced RAE prevalence.

Practical implications of these findings include the need to tailor talent identification and development strategies to the specific characteristics of each sport. Bio-banding, which involves grouping athletes by biological rather than chronological age, has shown promise in team sports for reducing selection bias (Cumming et al., 2017). Premier League academies in the UK have already adopted this approach to support the development of later-maturing players.

In individual sports, long-term development models that emphasize technical and psychological growth over early performance may help mitigate RAE, especially in sports such as tennis or gymnastics. Coaches play a crucial role and should be educated to recognize potential rather than current performance, incorporating assessments of biological maturity into their decisions. Similarly, sport governing bodies should promote flexible competition structures that enable fairer opportunities for late-born athletes.

While this study offers meaningful insights, several limitations must be acknowledged. Although multiple samples originated from the same primary studies, they were treated as independent observations for exploratory comparison. This approach may overestimate precision and should be interpreted with caution. The dataset predominantly included studies from Europe and North America, potentially limiting generalizability to other regions.

A further limitation concerns the absence of a standardized methodological quality assessment using a validated tool (e.g., Downs and Black or STROBE-based criteria). Although predefined inclusion criteria ensured a minimum level of data

completeness and relevance, variability in study design, sample characteristics, and statistical approaches across included studies may have introduced potential sources of bias, including selection bias, reporting bias, and heterogeneity-related bias. As no weighting based on study quality was applied, all included samples contributed equally to the synthesis, which may affect the precision and robustness of the comparative results.

In addition, the quantitative synthesis relied on odds ratios analyzed in their original (non-log-transformed) form. While log transformation is commonly recommended due to the asymmetric distribution of ORs, the present analysis prioritized interpretability and consistency with reporting in the primary studies. However, this approach may have influenced the distributional properties of the data and the sensitivity of parametric tests, particularly in sports with greater variability.

The exploratory nature of the quantitative synthesis and the absence of variance-based weighting should be considered when interpreting between-sport comparisons. Additionally, the analysis relied on secondary data from previously published studies, which varied in methodological rigor. Future research should expand geographic diversity, employ standardized RAE assessment protocols, and prioritize longitudinal designs to explore long-term outcomes of RAE in athletes' careers.

In summary, this study contributes to a better understanding of how the RAE differs between sport types and emphasizes the importance of adopting context-specific

strategies to foster equity and fairness in youth sport.

5. Practical Applications

The findings of this systematic review with a secondary quantitative synthesis highlight the need for sport organizations, coaches, and policymakers to recognize that the RAE is not uniform across sports but is strongly influenced by sport-specific demands and competition structures. In team sports such as football, ice hockey, and basketball, consistent RAE patterns suggest that current talent identification systems tend to favor relatively older athletes, which may lead to premature exclusion of later-born players with long-term potential. Practical strategies such as bio-banding, flexible age categories, and increased awareness among coaches can help ensure that selection processes are more inclusive and equitable. In individual sports, particularly gymnastics where RAE is most pronounced, long-term athlete development models emphasizing technical and psychological growth over early physical maturity may reduce bias. Conversely, in sports like swimming, where RAE is minimal, maintaining inclusive policies appears effective and should be encouraged. Overall, the study supports the adoption of developmentally appropriate training, competition formats, and coach education programs to reduce the disadvantages of relative age and to provide fairer opportunities for all young athletes, regardless of their birth month.

6. Conclusions

This systematic review with a secondary quantitative synthesis provides a comprehensive examination of RAE across team and individual sports. Team sports such as football, ice hockey, and basketball showed a consistent and moderately strong RAE with relatively low variability (mean OR = 1.29–1.32). In contrast, individual sports like tennis, swimming, and especially gymnastics demonstrated higher variability, with gymnastics displaying the highest prevalence (mean OR = 2.10) and swimming the lowest (mean OR = 1.20). Statistical tests confirmed that these differences between sport types and among individual disciplines were significant and practically meaningful.

Supplementary Materials: The following are available online at <http://eurjhm.com/index.php/eurjhm>, S1: Table 1: Shapiro–Wilk Test of Normality, Table 2: Levene’s Test of Homogeneity of Variances, Table 3: Descriptive Statistics of OR by Sport, Table 4: Post-hoc Comparisons and Effect Sizes. S2: PRISMA flow diagram. S3: Search Strategy.

Conflicts of Interest: The author declares no conflict of interest.

Ethics Statement: This study did not require ethical approval because it is based exclusively on the analysis of data previously published in peer-reviewed studies.

Data Availability Statement: The dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request.

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