scientific reports

OPEN

Relative age effect and its impact on athletic performance among Chinese elite youth male basketball players

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This study aimed to explore the presence and magnitude of relative age effects (RAEs) among elite male Chinese youth basketball players. A total of 728 adolescent players and 60 teams in the 2023 Chinese Student (Youth) Games were included. Player efficiency rating (PER) was calculated to evaluate individual performance, and the relative age team achievement (RATA) score was used to assess team-related RAEs. Partial correlation analysis was conducted to explore the relationships between relative age and performance parameters, with height and weight as control variables. The results indicate a skewed distribution of birth dates in the U-16 group. In contrast, the U-18 group exhibited a more balanced distribution. In the U-16 competitions, relative age had significant positive correlations with points, assists and PER. However, in the U-18 competitions, a significant positive correlation was only observed for assists. At the team level, in both U-16 and U-18 competitions, there was no significant correlation between the relative age and team performance indicators such as average point differential, winning percentage, and team efficiency. Given that RAEs in youth basketball may lead to inequitable talent selection and developmental opportunities, this phenomenon warrants attention, and measures should be implemented to mitigate potential selection bias and talent loss.

Keywords RAE, Youth sport, Talent identification, Adolescent development

Youth sports competitions are typically grouped according to physiological age, in which athletes born within the same calendar year compete against one another. Subtle differences in age between individuals in the same age group are referred to as relative age, and the immediate and long-term consequences resulting from relative age are known as relative age effects (RAEs)[1,2]. RAEs may cause selection bias in talent identification and development, whereby individuals born after the applied cutoff date gain some advantages, whereas peers born later are subjected to several disadvantages[3].

While numerous studies have demonstrated the prevalence of RAEs in team sports such as soccer[4–6], volleyball[7,8], and basketball[9–20], conflicting findings have emerged from basketball. Nakata and Sakamoto[9] observed that RAEs were significantly present in male Japanese basketball players, whereas their effects were minimal in female players[10]. Despite the apparent disparity in the distribution of birth dates among Brazilian adolescent basketball players, this phenomenon did not last and failed to generate a sufficient effect size to differentiate athletes' physical performance[11]. In addition, a disparity exists in the distribution of quarterly births among European male basketball U-16 and U-18 athletes, with the oldest athletes exhibiting more playing time. Relatively older athletes demonstrated superior performance in terms of total points and performance index ratings (PIR) when the results were normalized to playing time; however, these effects did not occur in female athletes[12]. A subsequent study of the European elite U-18 basketball tournament revealed that the number of athletes born in the first half of the year exceeded twice the number of athletes born in the second half of the year. Moreover, the study found that the quarter of birth was associated with competition performance of small forwards (defensive rebounds and fouls received) and centers (three-point throws scored and tried)[13].

Furthermore, Rubajczyk et al.[14] observed RAEs in both male and female groups in Polish youth basketball, and these effects demonstrated an influence on team success. In U-14 boys, players born in the first half of the year exhibited superior match results and PIR. While RAEs were observed in the Regional Talent Hubs and Basketball England Youth Teams, there were no significant differences in the birth quarter distribution based on playing time and among those who made a successful transition to England National Senior Teams[15]. Tascioglu

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et al.[16] observed that despite a higher proportion of players in the International U-16 Men Tournament born in the first quarter of the year, there was no statistically significant difference in the impact of the birth quarter on players' competition performance. Conversely, team performance exhibited a significant correlation with birth-quarter tendencies of players across the entire team. Moreover, RAEs in high-level professional leagues have demonstrated inconsistent results. Steingröver et al.[17] suggested that there was no tangible relationship between relative age and career length among National Basketball Association (NBA) players. In addition, relative age did not significantly influence the probability of reaching the NBA[18]. However, RAEs influence the talent selection for the Spanish national team, as athletes born in the second half of the year exhibit a decreased likelihood of successful selection[19]. Another study showed that athletes born near the beginning of the year in the Italian Basketball League had a higher likelihood of entering Division 1 or Division 2[20].

Despite the extensive body of studies conducted on RAEs, it is evident from these conflicting results that both the presence and magnitude of this phenomenon exhibit considerable variations across different national contexts. To the best of our knowledge, no study has investigated the influence of relative age on the performance of young Chinese basketball players or teams. Moreover, competition categorization in Chinese youth sports is typically based on two- or three-year age cohorts, and the maximum age disparity between athletes competing in the same category extends up to three years, thereby increasing the probability of RAEs in athletes. Furthermore, the Student (Youth) Games represent the pinnacle of youth basketball competition in China, with participating athletes typically drawn from the most proficient youth players in each city. The athletes generally undergo multiple stages of selection before attaining the opportunity to represent their respective cities. Consequently, these athletes are highly representative examples of the fundamental characteristics and competitive standards of young basketball players in China.

Therefore, the primary objectives of this study were: (1) to examine the distribution of birth quarters among Chinese elite youth male basketball players and analyze the proportion of quarterly distributions; (2) to investigate the potential correlation between an athlete's relative age and their performance in the Student (Youth) Games; (3) to explore the potential influence of a team's relative age tendency on their winning percentage and team efficiency in this tournament.

Methods
Participants
A total of 728 adolescent male players who played in the Chinese Student (Youth) Games (CSYG) Basketball Tournament in 2023 were included in this study. In the U-16 group, 408 players (age: 15.68 ± 0.5) and 33 teams were analyzed; in the U-18 group, 320 players (age: 17.4 ± 0.62) and 27 teams were analyzed. According to the rules of CSYG[21], the date of birth must be later than January 1, 2007, for players in the U-16 category and January 1, 2005, for players in the U-18 category. All data in the study were obtained from the official website of the 2023 CSYG U-16 and U-18 Men Basketball Tournament (www.cba.net.cn). The data on the website are available to the public; therefore, they do not require proof of review by an ethics committee or informed consent from participants.

Data collection
This study recorded the date of birth, height, and weight of all the participants. To quantify and analyze the RAEs in this tournament, the date of birth of the participants was categorized using two methodologies. First, the date of birth was transformed into birth quarters (BQ) and defined as follows: 1st quarter (BQ1) from January 1st to March 31st, 2nd quarter (BQ2) from April 1st to June 30th, 3rd quarter (BQ3) from July 1st to September 30th, and 4th quarter (BQ4) from October 1st to December 31st, respectively. Although monthly or weekly age distributions constitute valid measures, delineating the distribution of birth dates in quarters provides a more comprehensible and concise representation of distributional trends and facilitates international comparison. Therefore, this study used quarters to present trends in the distribution of birth dates. Second, to measure the RAEs on players' competitive performance with greater precision, the relative age of the youngest athlete among the participants was assigned a value of one, and the relative ages of the remaining participants were assigned values incrementally according to their respective ages. In comparison to monthly or weekly-based analyses, relative age values offer a more nuanced representation of subtle age differences among participants. Player statistics, including points, field goals, field goal attempts, free throws made, free throws attempts, offensive rebounds, defensive rebounds, assists, steals, blocks, fouls and turnovers were utilized to calculate the player efficiency rating (PER), while the team's winning percentage and statistics were employed to measure the team's performance in the tournament. Owing to official data availability, the players were divided into three playing positions: guard, forward and center.

Player efficiency rating (PER)
Research on basketball frequently utilizes player efficiency rating (PER) or performance index rating (PIR) to evaluate performance, but "personal fouls drawn" and "blocks against" were not provided by official website. In order to enhance the accuracy of the measurements, this study employed the PER formula developed by Hollinger[22] to quantify player efficiency. This formula incorporates 12 variables, and a single efficiency value is computed using distinct coefficients for each variable to assess the performance of players and teams in competition.

$$\begin{aligned}\text{Player Efficiency Rating} &= \text{Points} + 0.4 \times \text{Field Goal} - 0.7 \times \text{Field Goal Attempt}\\ &+ \text{Free Throw} - \text{Free Throw Attempt}\\ &+ \text{Offensive Rebound} + 0.3 \times \text{Defensive Rebound}\\ &+ 0.7 \times \text{Assist} + \text{Steal} + 0.7 \times \text{Block} - 0.4 \times \text{Foul} - \text{Turnover}\end{aligned}$$

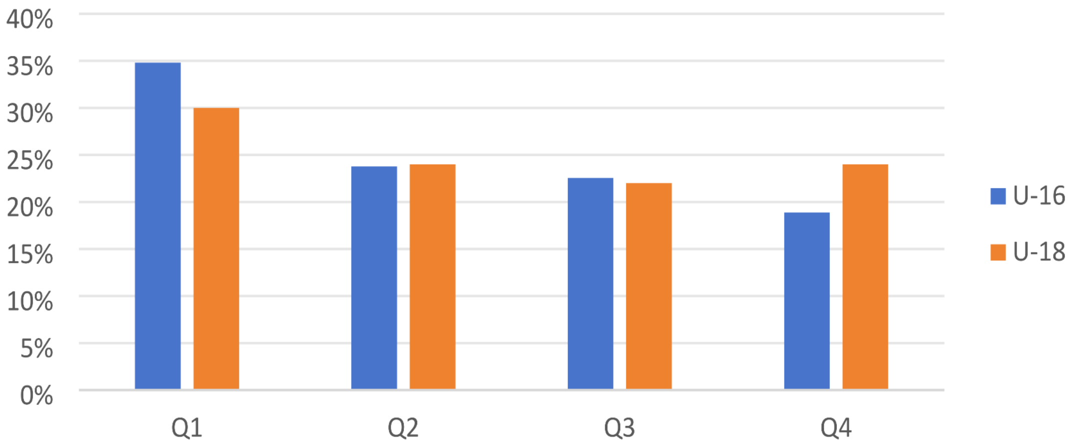

Fig. 1. Birthdate distribution of the U-16 and U-18 players. Q1-Q4: Birth Quarter.

		Q1	Q2	Q3	Q4	Total	EXP	χ2	*P*	OR (Q1 vs. Q4)	OR (Q2 vs. Q4)	OR (Q3 vs. Q4)
U−16	n	142	97	92	77	408	102	23.039	< 0.001	1.84 (1.53, 2.20)	1.26 (1.08, 1.47)	1.19 (1.04, 1.36)
U−18	n	97	76	70	77	320	80	5.175	0.161	1.26 (1.09, 1.45)	0.99 (0.84, 1.17)	0.91 (0.79, 1.05)

Table 1. The chi-square tests for the distribution of players' birth quarters. Q1-Q4: birth quarter; OR: odds ratio.

Relative age team achievement (RATA) score

This study used RATA scores to assess the RAEs for competitive performance of teams. This methodology draws on McLean's[23] counting voting system and Tasciou's[16] refinement. Initially, a certain value (relative age) was assigned to each participant. Subsequently, the assigned values of all players within the team were aggregated to derive the team's RATA score. Finally, the team's mean RATA score was calculated by dividing the team's RATA score by the number of players to ascertain whether a team demonstrated RAEs in player selection. The mean RATA score represents a trend associated with the date of birth, a higher mean RATA score indicates an increased likelihood of teams selecting older players.

Statistical analysis

The study employed Chi-square tests to ascertain the discrepancy between the observed and expected values of the distribution of the players' birth dates. Similar to previous studies in this field, the analysis was conducted under the premise that the distributions were uniform across all four quartiles[13,16,17]. According to Cobley et al.[2], this method, although not entirely precise, was actually a more cautious approach that might reduce the likelihood of a type I error. The Odds Ratio (OR) was calculated to reflect the proportional relationship between different birth quarters. Partial correlation analysis was used to test the correlation between relative age and parameters related to competitive performance, with height and weight as control variables. The team data included mean RATA, average point differential, winning percentage, and team efficiency. All statistical analyses were conducted using IBM SPSS software (version 30.0), and 95% confidence intervals were used for all tests.

Results

In the U-16 group, the percentages of athletes born in the first to fourth quarters were 34.8%, 23.8%, 22.5%, and 18.9%, respectively (Fig. 1). The chi-square value ($\chi2$) was 23.039 ($p < 0.001$), indicating a statistically significant imbalance in the distribution of athletes births across quarters. The odds ratio (OR) results showed that the ratios of BQ1, BQ2, and BQ3 to BQ4 were 1.84, 1.26, and 1.19, respectively, suggesting that a lower percentage of players were born in the fourth quarter compared to the other three quarters (Table 1). By contrast, the U-18 competition demonstrated a more balanced distribution of players' birth dates, with 30.3%, 23.8%, 21.9%, and 24.1% of players born in quarters 1 to 4, respectively.

Among U-16 players, those born in Q1 were overrepresented across all positions, with more significant disparities observed for forwards and centers, whereas the differences observed among guards were relatively less substantial. This uneven distribution was also evident among the guards of U-18 players; however, this skewed distribution was diminished for the forwards and centers (Fig. 2).

Table 2 shows the correlation between the participants' relative age and performance. Significant positive correlations were found in many competitive statistics ($p < 0.001$), such as minutes played, PTS, DREB, AST,

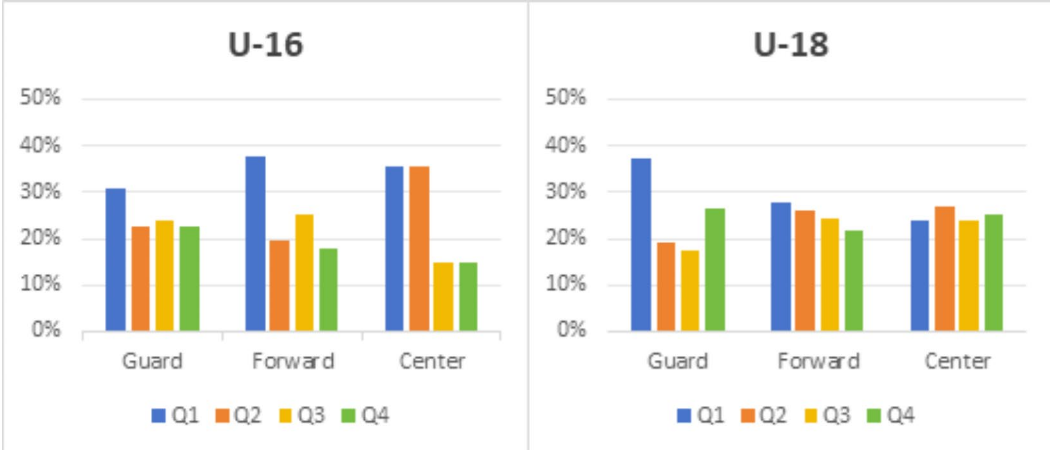

Fig. 2. The distribution of players' birth quarters by playing position.

Relative age				
	U−16		U−18	
	Results	p	Results	p
Height	0.007	0.830	0.047	0.214
Weight	0.038	0.265	0.072	0.063
Min	0.219***	< 0.001	0.031	0.585
PTS	0.244***	< 0.001	0.078	0.165
FG%	0.040	0.423	0.105	0.062
FT%	0.034	0.496	0.038	0.495
OREB	0.083	0.094	0.037	0.514
DREB	0.168***	< 0.001	0.020	0.722
AST	0.182***	< 0.001	0.115*	0.040
STL	0.249***	< 0.001	0.039	0.491
BLK	−0.005	0.926	−0.072	0.203
TOV	0.171***	< 0.001	0.034	0.542
PF	0.184***	< 0.001	−0.012	0.828
PER	0.177***	< 0.001	0.109	0.051

Table 2. Kendall's Tau B correlation results for the relative age and height or weight. The partial correlation analysis of relative age and competition performance. Min: minutes played; PTS: points; FG%: field goal percentage; FT%: free throw percentage; OREB: offensive rebounds; DREB: defensive rebounds; AST: assists; STL: steals; BLK: blocks; TOV: turnovers; PF: personal fouls; PER: player efficiency rating. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

STL, TOV, PF, and PER, in the U-16 competition. In contrast, a positive correlation was only observed in AST for U18 competitions ($p < 0.05$).

Table 3 presents the correlations between relative age and competitive statistics per minute among U-16 and U-18 players. Significant positive correlations were observed between relative age and PTS ($p < 0.001$), STL ($p < 0.001$), AST ($p < 0.05$)and PER ($p < 0.05$) in the U-16 competition. However, there were no statistically significant correlations between relative age and performance in the U-18 competitions. Figure 3a-d illustrate the relationships between relative age and players' PER, as well as PER per minute. The figures show that there is a slight increase in player efficiency as relative age increases during this tournament.

Table 4 presents the partial correlation analysis results for the mean RATA, RATA ranking, average point differential, winning percentage and efficiency of the U-16 and U-18 teams in CSYG. The p-values of all RATA scores with the team success test exceeded 0.05, indicating that the relative age of the teams did not have a significant impact on the differences in the team's competitive performance in the tournament.

Discussion

The primary purpose of this study was to investigate the presence and magnitude of RAEs in elite Chinese youth male basketball players. We utilized normalized data according to minutes played, which provided a more precise measure of the effects of relative age on athletes' competitive performance, in line with previous

Relative age				
	U–16		U–18	
	Results	p	Results	p
PTS/min	0.192***	< 0.001	0.082	0.143
FG%/min	−0.095	0.057	0.027	0.633
FT%/min	−0.116*	0.019	0.042	0.453
OREB/min	−0.036	0.471	0.043	0.450
DREB/min	0.026	0.600	0.024	0.663
AST/min	0.101*	0.043	0.101	0.072
STL/min	0.187***	< 0.001	0.025	0.654
BLK/min	−0.078	0.118	−0.093	0.097
TOV/min	0.028	0.570	0.056	0.317
PF/min	−0.016	0.743	−0.029	0.609
PER/min	0.126*	0.011	0.107	0.056

Table 3. The partial correlation analysis of relative age and performance per minute played. MIN: minutes played; PTS: points; FG%: field goal percentage; FT%: free throw percentage; OREB: offensive rebounds; DREB: defensive rebounds; AST: assists; STL: steals; BLK: blocks; TOV: turnovers; PF: personal fouls; PER: player efficiency rating. *$p < 0.05$, ***$p < 0.001$.

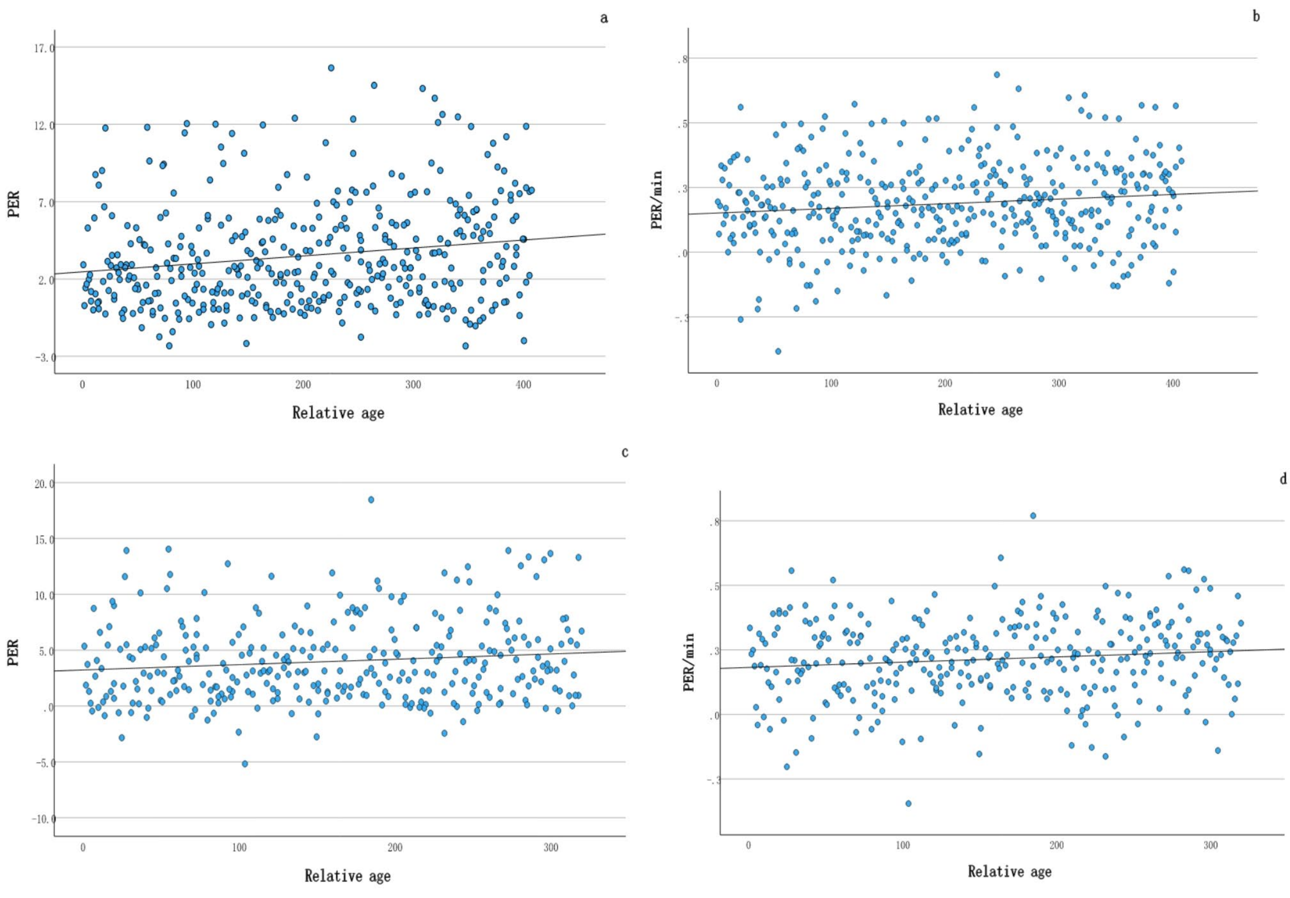

Fig. 3. (**a**–**d**). (**a**): PER in the U-16; (**b**): PER/min in the U-16; PER in the U-18; PER/min in the U-18.

investigations[12,13,24]. To the best of our knowledge, this is the first study to use height and weight as control variables to examine the RAEs on player and team competition performance. Furthermore, we applied mean RATA scores to reduce the potential confounding influence of team size on the study's findings.

We found a skewed distribution of birth dates among male Chinese youth U16 basketball players. The frequency of athletes born in the first quarter was notably higher, with the number of births in this quarter being 1.84 times that in the fourth quarter. This finding is consistent with previous studies on the RAEs of basketball

	Score	1	2	3	4	5
U−16	Mean RATA	–				
	RATA ranking	−0.981***	–			
	Average point differential	0.074	−0.054	–		
	Winning percentage	0.013	0.028	0.833***	-	
	Team efficiency	0.019	−0.005	0.806***	0.802***	-
U−18	Mean RATA	–				
	RATA ranking	−0.984***	–			
	Average point differential	0.201	−0.186	–		
	Winning percentage	0.270	−0.212	0.805***	–	
	Team efficiency	0.136	−0.132	0.917***	0.849***	–

Table 4. The partial correlation analysis results for the mean RATA, RATA ranking, average point differential, winning percentage and team efficiency. ***$p < 0.001$.

player selection[15,16,24,25]. However, this uneven distribution was attenuated in the U18 competition, with an OR odds of 1.26 for players born in the first versus fourth quarter, while the number of births in the fourth quarter exceeded that in the second and third quarters. Similar phenomena have been observed in other studies, such as a decrease in the skewed distribution of birth quarters among German elite basketball players from JBBL (U16) to NBBL (U19) participants[26]. The distribution of birth dates among Turkish youth basketball players in the 17-, 18-, and 19-year age groups exhibited an uneven trend, but the differences gradually decreased as age progress[27]. The aforementioned results indicate that RAEs exhibit greater significance in youth stage[28]. However, as age increases, other factors become increasingly influential, gradually weakening the influence of relative age[15,27].

In addition, this study observed a significant correlation between relative age and performance parameters as well as variations in this effect across different age cohorts. In the U16 competitions, older players demonstrated superior performance in terms of points scored ($p < 0.001$), defensive rebounds ($p < 0.001$), assists ($p < 0.001$), steals ($p < 0.001$), and PER ($p < 0.001$), and they generally had longer playing time ($p < 0.001$). Consequently, these disparities in performance can be attributed to inequitable playing opportunities. However, when the data were standardized based on playing time, RAEs were significantly attenuated but remained present, as evidenced by the points scored ($p < 0.001$), steals($p < 0.001$) and PER ($p < 0.05$). Thus, older players demonstrated superior performance, independent of the minutes spent in competitions. These findings are consistent with the results of previous studies[12,13]. In contrast, for the U18 competitions, the influence of relative age was observed solely in the assists ($p < 0.05$). Moreover, when utilizing standardized data based on playing time, no significant association was found between the relative age and performance parameters. A plausible explanation for this phenomenon is that the significance of technical and tactical proficiency gradually outweighs the relative age as athletes accumulate years of training. Furthermore, with aging, athletes tend to have enhanced psychological stability, which further mitigates the disparity in relative age.

Furthermore, this study explored the correlation between the relative age of teams and competitive performance. In this tournament, no significant correlation was observed between the mean RATA score and the average point differential, winning percentage, or efficiency of teams in the U-16 and U-18 competitions. This finding suggests that although youth teams demonstrated a tendency to select older athletes, this preference does not have a substantial enough impact to enhance team performance in Chinese Student (Youth) Games. Additionally, our analysis revealed no significant relationship between players' relative age and physical attributes of height or weight. This result does not corroborate the hypothesis that older athletes obtain a competitive advantage because of their enhanced physical and mental maturity[29]. This discrepancy may be attributed to the ages of the participants, as the growth processes of the participants in this study were nearly finished. However, while height and weight may reflect physical characteristics, direct assessments of biological maturity, such as Peak Height Velocity or Tanner Stages, remain uninvestigated. Physical stature may still be a factor influencing the superior performance and increased competitive opportunities of older players, especially in younger levels of competition.

Overall, RAEs were evident among Chinese elite male basketball players, with this phenomenon being more pronounced in relatively younger U-16 competitions. Consequently, this effect has the potential to introduce bias into talent selection process and results in inequitable competitive opportunities at an early stage. Over time, this bias could potentially lead to more pronounced results in talent identification and development and may influence the adult field, as evidenced by Brustio[30]. In addition, studies on RAEs in Chinese tennis have similarly found an uneven distribution of athletes' birth dates[31,32]. Therefore, this phenomenon necessitates attention and potential interventions to mitigate the impact of RAEs in youth basketball. Several possible solutions include: (1) Bio-banding. Instead of using chronological age, bio-banding organizes athletes based on their biological maturity. This method ensures that physically mature but younger players compete against similar developmental levels, reducing selection biases that favor early born athletes. Several sports organizations have effectively adopted bio-banding, leading to more equitable competition and improved talent nurturing processes[33,34]. (2) Player labeling. Labeling players according to different physical maturity, technical and tactical abilities, or developmental stages enables coaches and team managers to have a clearer understanding of individual players' characteristics so that they can develop appropriate training programs and development paths for players at different stages[35]. (3) Adjusted selection criteria. Programs for identifying talent should look beyond immediate physical characteristics, encompassing technical skills, mental decision-making capabilities, and the potential for long-term growth. Rather than prioritizing early developers, national teams and clubs ought to implement multi-year assessment periods to methodically evaluate players progress over time[36]. (4) Awareness and education for coaches. Provide education to coaches and scouts that emphasizes the important role of training experience and potential in the performance and development of young athletes to bring about a more equitable developmental pathway[35,37]. (5) Grade grouping. Educational institutions in China mandate that students born between September 1 and August 31 of the subsequent year enroll in the same academic grade. This subdivided grouping methodology could be adopted for youth sports to reduce age disparities among participants.

Several limitations should be acknowledged regarding this study. Due to the constraints of the competition statistics available on the official website, player efficiency rating (PER) was used to assess players' competitive performance. Although this method has been adopted in several studies, it differs from the approach using performance index rating(PIR) and may potentially limit the comparability of the findings of this study with those of international studies. Moreover, the study did not examine the presence of RAEs among Chinese female youth basketball players, resulting in unclear athletes selection criteria for female youth basketball players and uncertainty regarding potential RAEs on athletic performance and team success.

Conclusions

This study demonstrated the existence of relative age effects (RAEs) among young elite Chinese male basketball players. These effects are reflected in the skewed distribution of athletes' birth dates and playing positions. Additionally, older players have shown superior performance in specific competition statistics. This phenomenon has the potential to give rise to inequitable talent selection and development opportunities. Nevertheless, in the Chinese Student (Youth) Games (CSYG), this effect did not have a significant impact on team performance. It is of utmost importance to pay close attention to RAEs among youth basketball players and to implement measures aimed at mitigating potential selection bias and preventing talent loss.

Data availability

The data in this study are available on website: https://osf.io/hb9wf/. with identifier: DOI 10.17605/OSF.IO/HB9WF.

Received: 27 November 2024; Accepted: 11 March 2025
Published online: 19 March 2025

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Acknowledgements
This manuscript does not require additional acknowledgements for any individual or group.

Author contributions
Conceptualization: Haitong Yu, Chengbo Yang; Methodology: Haitong Yu; Data collection: Haitong Yu; Data analysis: Haitong Yu; Software: Haitong Yu; Funding acquisition: Chengbo Yang; Write the original draft: Haitong Yu; Review and editing: Haitong Yu, Chengbo Yang. All authors have read and agreed to the current version of the manuscript.

Funding
Prof. Chengbo Yang was supported by the Sichuan Province Science and Technology Support Program(CN) (2023YFS0452).

Declarations

Competing interests
The authors declare no competing interests.

Additional information

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