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ORIGINAL RESEARCH

Can Training Background Offset the Disadvantage Associated With Relative Age Effect on Perceptual-Cognitive Skills From Childhood Into Adolescence?

Xiaoyu Zhang,[1] Freddy Maso,[2] Brigitte Ekpe-Lordonnois,[3] Tom Poncelet,[1] Gael Ennequin,[1] Anthony J. Blazevich,[4] and Sébastien Ratel[1]

[1]Université Clermont Auvergne, Clermont-Ferrand, France; [2]Montferrand Sports Association, Clermont-Ferrand, France; [3]Optimeyes, Clermont-Ferrand, France; [4]Centre for Human Performance, School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

Purpose: The aim of this study was to investigate the extent to which relative age effect (RAE) impacts the development of perceptual-cognitive skills and how training background may potentially offset RAE from childhood into adolescence. ***Method:*** One hundred sixty-five 10- to 16-year-old male participants were divided into 8 groups based on their birth quartiles (BQ_1 [January–March], BQ_2 [April–June], BQ_3 [July–September], and BQ_4 [October–December]) and training background (moderately trained: 1–2 sessions/wk and well-trained: 4–5 sessions/wk). Their perceptual-cognitive skills were evaluated using a 3D multiple-object tracking task (ie, the NeuroTracker [NT]) with (3D) and without (2D) stereopsis. ***Results:*** In moderately trained children, NT scores progressively decreased from BQ_1 to BQ_4, with a significant difference between the first 3 birth quartiles and BQ_4 ($P < .01$), independent of stereopsis. In well-trained children, however, no significant differences were detected in NT scores between quartiles, and well-trained children in BQ_4 exhibited NT scores comparable to moderately trained children in the first 3 quartiles. ***Conclusion:*** RAE showed a significant disadvantage on the perceptual-cognitive scores in moderately trained children born in BQ_4. However, well-trained children born in BQ_4 performed similarly to other well-trained children and to moderately trained children born in the first 3 birth quartiles, meaning that training background may offset the disadvantage associated with RAE from childhood into adolescence.

Keywords: stereopsis, multiple-object tracking task, age, birth quartile

Key Points

- Moderately-trained children born during the first three birth quartiles in a year outperformed their peers born later in the last birth quartile on the perceptual-cognitive scores.
- Well-trained children born late in the year matched the perceptual-cognitive performance of moderately-trained early-born peers, suggesting training may counteract relative age disadvantages.
- These findings highlight how training background may offset the relative age effect on perceptual-cognitive skills during childhood and adolescence, which is crucial for talent identification and long-term athlete development.

Perceptual-cognitive skills, defined as "the brain's capacity to extract contextual information from dynamic visual scenes,"[1] are determinants of performance in many sports. These skills manifest in athletes through their ability to anticipate and make decisions, showcasing their visual capacity and game intelligence.[2] To enhance and assess these skills, tools like the NeuroTracker (NT)—software paired with a 3D screen that enables users to track multiple moving objects in an immersive environment[3]—have been developed. This 3D multiple-object tracking (3D-MOT) task engages multiple neural networks within the central nervous system to improve visual and attentional abilities, working memory, and executive function.[4]

The perceptual-cognitive adaptations athletes may experience in response to sports training might theoretically be constrained by their individual characteristics. In youth sport, one of the most influential individual constraints is chronological age, so athletes are usually pooled with others within their birth year.[5] However, there can be a difference of nearly 1 year between athletes born at the beginning (relatively older) versus the end (relatively younger) of a year, so they have a different "relative age."[6] Differences caused by variation in relative age within the same selection year are known as relative age effects (RAEs),[7] which can have significant consequences for an athlete's sports career. Numerous studies have examined the RAE in sports.[8,9] A significant body of research aimed at evaluating birth date distribution in various sports has shown an overrepresentation of athletes born closer to the beginning of the selection year, that is, the first and second birth quartiles (BQ_1 and BQ_2), as compared with those born later (third and fourth BQs, ie, BQ_3 and BQ_4). Several studies have shown this asymmetry both in individual[8,10] and team sports.[11,12] However, the extent to which relative age impacts the development of perceptual-cognitive skills specifically, particularly during the transition from childhood into adolescence, remains underexplored.

Ennequin https://orcid.org/0000-0003-4485-0800
Blazevich https://orcid.org/0000-0003-1664-1614
Ratel (sebastien.ratel@uca.fr) is corresponding author, https://orcid.org/0000-0003-2471-158X

Several factors, including stereopsis and training background, can influence perceptual-cognitive skills. Stereopsis, defined as the ability to perceive depth and 3D structure from binocular vision, facilitates performance in dynamic environments, particularly when athletes need to track multiple moving objects in 3D space.[13] Of particular note, Plourde et al[3] found that performance on a 3D-MOT task was superior in stereoscopic (3D) than nonstereoscopic (2D) conditions for both children aged 7–12 and adults aged 18–40 years. Additionally, training background has been shown to impact perceptual-cognitive abilities. For example, video-based perceptual training improved decision making during small-sided games in adult female soccer players,[14] and 3D-MOT perceptual-cognitive training enhanced passing decision making ability in adult male soccer players, demonstrating its potential to transfer into on-field performance.[15]

Despite the relevance of these factors, the influence of sports training background and stereopsis on the RAE in perceptual-cognitive skills from childhood into adolescence remains unclear. While some studies have shown that RAE is prevalent in youth football teams,[5,16] findings in older categories are more controversial. For instance, Gonzalez-Villora et al[17] found no RAE in adult professional soccer teams, yet Bäumler[18] found an effect in German professional adult football players, despite RAE decreasing with increasing age. Recent findings also suggest that players who are born later in a selection year catch up to their peers by adulthood.[5] Although relatively younger players are underrepresented in absolute numbers at the senior level, some may nonetheless reach similar levels of success (eg, being drafted or selected) as those born earlier in the year.[19] This phenomenon has been discussed in the context of the "underdog hypothesis," which posits that relatively younger athletes who remain in competitive systems often develop compensatory attributes such as technical skills, resilience, or motivation that enable them to succeed once age-related advantages diminish.[20] In general, such patterns are more frequently observed in senior categories, particularly in strength-based sports.[21] However, few studies have explored how this phenomenon, particularly in relation to training background, may influence the development of perceptual-cognitive skills during childhood and adolescence. This highlights a gap in the current literature.

Given the current research gaps, the purposes of the present study were to investigate the concurrent effects of relative age, training background, and stereopsis on the development of perceptual-cognitive skills (using NT) from childhood into adolescence. We hypothesized that between 10 and 16 years of age: (1) athletes born earlier in the selection year will demonstrate superior perceptual-cognitive performance compared with their relatively younger peers; (2) training background will offset the natural disadvantage associated with RAE, notably in children born at the end of the selection year; and (3) children and adolescents will have superior perceptual-cognitive performance under stereoscopic (3D) than nonstereoscopic (2D) conditions because of their regular training regimen, mainly in the trained individuals since their central nervous system should be more stimulated in 3D dynamic visual scenes.

Materials and Methods

Participants

A total of 165 boys aged 10–16 years (Table 1) were recruited from the Montferrand Sports Association (Clermont-Ferrand, France) and divided into 8 groups: BQ_1 and well-trained (n = 20), BQ_1 and moderately trained (n = 31), BQ_2 and well-trained (n = 11), BQ_2 and moderately trained (n = 37), BQ_3 and well-trained (n = 7), BQ_3 and moderately trained (n = 22), BQ_4 and well-trained (n = 23), and BQ_4 and moderately trained (n = 14). Montferrand Sports Association is a well-known regional sports club in France, recognized for developing young athletes through structured training and competitive selection. The sample reflects a departmental-to-regional sporting level youth population. The method of birth quartiles was used to assign birth dates throughout the year, with BQ_1, BQ_2, BQ_3, and BQ_4 representing children and adolescents born between January and March, April and June, July and September, and October and December, respectively. Children and adolescents were considered as well-trained or moderately trained based on their weekly training regimen in soccer or rugby (well-trained: 4–5 weekly sessions; moderately trained: 1–2 weekly sessions). All participants were healthy and exhibited normal binocular stereoacuity as measured by the TNO and Lang I tests.[22] The present study was approved by an institutional ethics review board (CERSTAPS; IRB 00012476-2022-31-10-203) and was conducted in accordance with the sixth *Declaration of Helsinki* regarding the use of human subjects. Written assent was obtained from all participants, and parental or guardian consent was also secured prior to testing.

Experimental Design

Participants were tested in a single experimental session in which participants' physical characteristics (anthropometric measurements, visual acuity evaluation, and maturity status assessment) were obtained, test procedures explained, and perceptual-cognitive

Table 1 Participants' Physical Characteristics and Perceptual-Cognitive Skill Scores

	BQ_1 (N = 51)		BQ_2 (N = 48)		BQ_3 (N = 29)		BQ_4 (N = 37)	
	WT (n = 20)	MT (n = 31)	WT (n = 11)	MT (n = 37)	WT (n = 7)	MT (n = 22)	WT (n = 23)	MT (n = 14)
Age, y	13.6 (0.9)	13.6 (1.3)	13.5 (1.0)	13.4 (1.3)	13.0 (0.9)	13.4 (1.3)	12.4 (1.1)	11.5 (1.3)
Height, cm	166.0 (10.9)	161.5 (10.5)	162.1 (9.9)	159.0 (11.2)	163.2 (10.1)	163.5 (11.3)	153.1 (10.5)	150.6 (10.4)
Body mass, kg	58.1 (15.5)	49.2 (8.8)	58.6 (10.6)	47.3 (10.7)	54.7 (9.8)	54.0 (13.3)	49.2 (16.2)	40.1 (8.1)
BMI, kg/m^2	20.7 (3.5)	18.8 (2.3)	22.2 (2.5)	18.5 (2.2)	20.4 (2.4)	19.9 (2.9)	20.6 (4.8)	17.5 (1.7)
NT score	1.09 (0.30)	1.14 (0.32)**	1.14 (0.33)	1.09 (0.36)***	0.94 (0.21)	1.05 (0.31)**	1.07 (0.30)##	0.87 (0.36)

Abbreviations: BM, body mass; BMI, body mass index; BQ_1, first birth quartile; BQ_2, second birth quartile; BQ_3, third birth quartile; BQ_4, fourth birth quartile; MT, moderately trained (1–2 weekly sessions); NT score, perceptual-cognitive skill score pooling 2D and 3D conditions (NT scores were calculated considering both conditions since no significant interaction effect was obtained between stereopsis and relative age); WT, well-trained (4–5 weekly sessions). Data are presented as mean (SD). **Significantly different from BQ_4 within the same training background at $P < .01$. ***Significantly different from BQ_4 within the same training background at $P < .001$. ##Significantly different between groups within the same birth quartile at $P < .01$.

skills assessed using a 3D-MOT task (see below for details). 3D-MOT task performance was tested under 2 conditions, with (3D) and without (2D) stereopsis, respectively, with the order of conditions assigned randomly and a minimum 10-minute rest allowed between. To prevent any training effects, participants were allowed only one attempt per test.[23] All participants underwent testing under standardized conditions to maintain consistency and minimize potential variability from external factors. The experimental setup was carefully controlled, with all participants using the same 165.1 cm screen, positioned at a 30° viewing angle and a fixed testing distance of 2.6 m. Furthermore, assessments were conducted in a standing position—a deliberate choice reflecting the postural demands of sports activities. This decision aligns with the findings of Faubert and Sidebottom,[24] who highlighted the influence of posture on NT performance. No participants had prior experience with the 3D-MOT task before the study. A trained experimenter conducted the data collection, with each session lasting approximately 30 minutes per participant. An independent research assistant not involved in data collection verified all data. Measurements were taken between October 2022 and March 2024.

Anthropometric Characteristics

Body mass (BM) was recorded using a digital scale (TANITA, BC-545N), and standing height was measured with a portable stadiometer while participants stood barefoot (TANITA, HR001). Sitting height was assessed using the stadiometer as participants sat on the floor with their back against a wall. BM and height measurements were taken with participants in light clothing and without shoes. BM index was calculated by dividing BM (in kilograms) by the square of standing height (in meters squared). Skinfold thicknesses were assessed at the triceps and subscapular areas using a Harpenden caliper (British Indicators Ltd), with the average calculated from 3 consistent measurements. All measurements were taken on the right side of the body.

3D-MOT Task

The 3D-MOT task used in this study involved tracking 8 spheres within a virtual 3D cube (Figure 1). At the start, all spheres appeared in white (presentation phase; Figure 1a). Then, 3 spheres briefly turned gray for 1 second to mark them as targets (indexing phase; Figure 1b). The spheres then returned to white and began moving in random directions within the cube (movement phase; Figure 1c), with their paths including interactions like collisions, occlusions, and bouncing off the cube's walls. After 6 seconds, the movement stopped, and participants were asked to identify the 3 initial target spheres (identification phase; Figure 1d). Feedback was then provided by highlighting the correct target spheres (Figure 1e).

A speed threshold was determined for each condition (with and without stereopsis) using a 1-up, 1-down staircase method according to the approach outlined by Levitt.[25] Each trial began at a standard speed of 1 NT unit, equating to a virtual speed of 68 cm/s. Correct identification led to a speed increase of 0.05 log units, whereas errors resulted in an equivalent decrease, maintaining a threshold criterion of 50%. The staircase procedure ended after 20 inversions, and the threshold speed was calculated based on the mean of the last 4 inversions. Three targets were chosen to ensure that children and adolescents could complete the task without losing interest during the session.[3] Stereoscopic perception was induced using anaglyph techniques, with participants wearing red–blue glasses. In the stereopsis condition, the disparity range was set from 0 to 150 arc seconds, depending on the spheres' locations within the virtual cube.

Statistical Analysis

The data were assessed for normality of distribution and homogeneity of variances using the Shapiro–Wilk and Bartlett tests, respectively. A 3-way analysis of variance was conducted to evaluate the effects of relative age, training background, stereopsis, and their interaction on participants' NT scores (speed thresholds). When significant main or interaction effects were detected by the analysis of variance, a Fisher least significant difference post hoc test was conducted to compare the means. The effect size was calculated using partial eta-squared (η_p^2), categorized as follows: ~.01 = small effect, ~.06 = moderate effect, and ≥.14 = large effect.[26] The threshold for statistical significance was established at $P < .05$. All statistical analyses were performed using Statistica 8.0 software. Results are reported in the text and tables as mean (SD).

Results

The physical characteristics and NT performance scores of the 8 groups are shown in Table 1. No significant relative age × training

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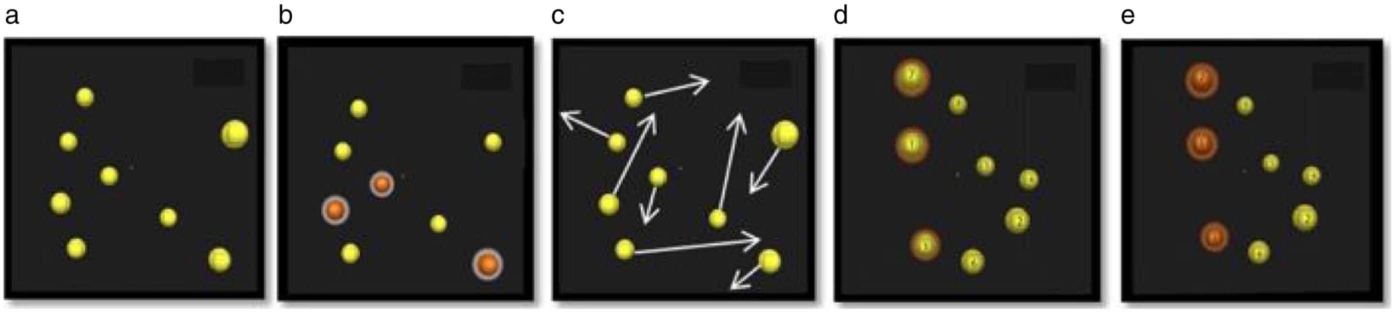

Figure 1 — Five steps of the 3D-MOT task. (a) Presentation phase where 8 spheres are shown in a 3D volume space, (b) indexing phase where 3 spheres (targets) change color (red/gray) and are highlighted (hallo) for 1 s, (c) movement phase where the targets indexed in stage b return to their original form and color and all spheres move for 6 s crisscrossing and bouncing off of each other and the virtual 3D volume cube walls that are not otherwise visible, and (d) identification phase where the spheres come to a halt and the observer has to identify the 3 spheres originally indexed in phase b. The spheres are individually tagged with a number so the observer can give the number corresponding to the original targets, and (e) feedback phase where the subject is given information on the correct targets. 3D-MOT indicates 3D multiple-object tracking. Reprinted from Plourde et al.[3]

background × stereopsis interaction effects were found for chronological age, BM, standing height, or BM index.

Main effects of relative age ($F_{3,314} = 4.415$, $P < .01$, $\eta_p^2 = .04$) and stereopsis ($F_{1,314} = 17.762$, $P < .001$, $\eta_p^2 = .05$) were identified, but there was no main effect of training background on NT performance. In addition, no significant interaction effects were found between relative age and stereopsis; training background and stereopsis; or between relative age, training background, and stereopsis, meaning that stereopsis did not influence the effects of training background or relative age.

However, there was a significant relative age × training background interaction effect ($F_{3,314} = 3.254$, $P = .022$, $\eta_p^2 = .03$). Post hoc comparisons using Fisher least significant difference test indicated that, in moderately trained children, BQ_1 achieved significantly higher scores than BQ_4 ($P < .01$), whereas BQ_2 and BQ_3 also outperformed BQ_4 ($P < .01$ at least; Figure 2). In contrast, no significant differences were observed in NT performance scores between the different birth quartiles in well-trained children.

Finally, BQ_4 NT performance scores in well-trained children were statistically similar to moderately trained children born in BQ_1, BQ_2, and BQ_3.

Discussion

The present study examined the effects of relative age, training background, and stereopsis as well as their interaction on perceptual-cognitive skills using the NT task. Significant effects of relative age and stereopsis but not training background were observed. Notably, an interaction was found between relative age and training background such that while no differences were detected between the birth quartiles in well-trained children, BQ_1, BQ_2, and BQ_3 outperformed those in BQ_4 in moderately trained children.

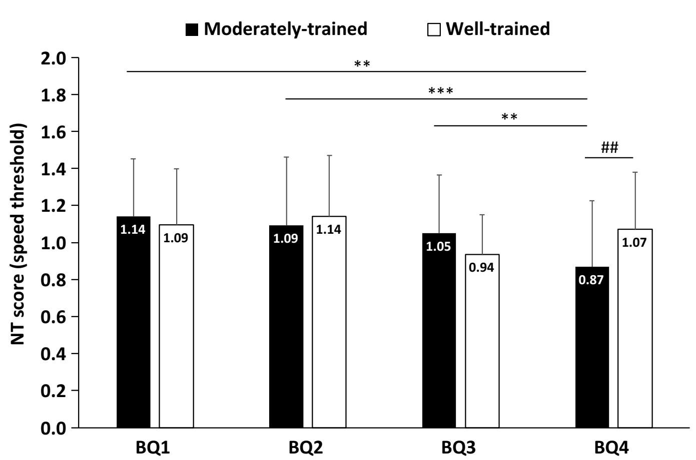

Figure 2 — NT scores according to birth quartiles and training background. NT score: perceptual-cognitive skill score pooling 2D and 3D conditions (NT scores were calculated considering both conditions since no significant interaction effect was obtained between stereopsis and relative age). BQ_1: first birth quartile (born between January and March), BQ_2: second birth quartile (born between April and June), BQ_3: third birth quartile (born between July and September), and BQ_4: fourth birth quartile (born between October and December). MT indicates moderately trained (1–2 weekly sessions); NT, NeuroTracker; WT, well-trained (4–5 weekly sessions). **Significantly different from BQ_4 in moderately trained children at $P < .01$. ***Significantly different from BQ_4 in moderately trained children at $P < .001$. ##Significantly different between groups within the BQ_4 at $P < .01$.

Furthermore, well-trained children in BQ_4 performed similarly to moderately trained children in BQ_1, BQ_2, and BQ_3 whether tested in 2D or 3D (ie, regardless of stereopsis), indicating that training background may have offset the disadvantage associated with children and adolescents being born at the end of the year.

The significant effect of relative age on perceptual-cognitive skills, as measured by the NT task, adds a compelling dimension to the understanding of how relative age influences perceptual-cognitive performance. The present results suggest that moderately trained children born earlier in the selection year (BQ_1, BQ_2, and BQ_3) generally outperform those born later (BQ_4) on tasks requiring perceptual-cognitive skills. This finding is consistent with the extant RAE literature, which highlights that relatively older children tend to benefit from physical, cognitive, and emotional advantages compared with their younger peers in the same year group.[9] It may be that children born earlier in the selection year have a longer period of neurological and cognitive development, which translates into superior performance in tasks requiring rapid information processing, decision making, and spatial awareness. Scammon's growth curves emphasize the substantial development of the central nervous system during childhood, especially in the early years,[5,27] and indicate that children born earlier in the selection year may exhibit more advanced neural maturation, potentially enhancing their perceptual-cognitive abilities.[28] Furthermore, some studies have shown that RAE might create disparities in how children engage with training and learning opportunities.[29] Children who are relatively older within their cohort might receive more positive feedback and reinforcement due to their advanced skills, which in turn could boost their confidence and motivation to engage in cognitively demanding tasks.[30] Over time, this could lead to a compounding effect in which older children continue to improve their perceptual-cognitive skills while relatively younger children might lag behind, not necessarily due to a lack of ability but due to a lack of developmental opportunity and confidence.[31] This reinforces the need to consider the timing of cognitive skill assessments and interventions as well as the potential long-term impacts of RAE on both academic and athletic performances.

The results of the present study clearly show a stereopsis advantage in perceptual-cognitive performance. Specifically, children and adolescents performed better in trials with stereopsis (3D) than without (2D), thus showing better perceptual-cognitive skill. This finding is consistent with the previously published data by Plourde et al,[3] showing that the stereopsis advantage is present in both 7- to 12-year-old children (~17% vs 20% in the present study) and 18- to 40-year-old adults (~21%). This may be because stereopsis enhances depth perception and spatial awareness, allowing individuals to process and respond to visual information more quickly, which plays an important role in processing dynamic stimuli and thereby improves perceptual-cognitive skill.[24] The lack of interaction between stereopsis and relative age in the present study suggests that the advantage conferred by strong stereoscopic vision is consistent regardless of individual's relative age within the cohort. That is, benefits of stereopsis on NT performance are uniform regardless of whether a participant is born earlier or later in the selection period. This finding is particularly interesting because it challenges some expectations based on the RAE literature. While RAE often gives older individuals an initial advantage due to greater physical or cognitive maturity,[29] the advantage does not appear to interact with stereopsis ability. This could mean that while RAE may offer certain early developmental benefits, these are neither amplified nor diminished by the ability to discern or track the movement of objects in 3D space.

Interestingly, the effects of relative age on perceptual-cognitive skills were not uniform across different training backgrounds. In moderately trained children, a clear pattern emerged where those in the first 3 quartiles (BQ_1, BQ_2, and BQ_3) outperformed those in the fourth quartile (BQ_4; Table 1 and Figure 2). These results highlight for the first time that, among moderately trained children (ie, 2 sessions/wk in soccer or rugby), those who are relatively older (BQ_1, BQ_2, and BQ_3) perform better on NT tasks than their younger peers (BQ_4). This pattern is consistent with the established understanding of the RAE, where older children within a cohort often have developmental advantages over their younger counterparts.[5] As Brustio et al[6] found in their study on the incidence of RAE in elite Italian football clubs, a more pronounced RAE could be observed in youth compared with senior players. This could be because moderately trained children rely more on their inherent developmental advantages, such as maturity and physical abilities, which are influenced by RAE.

In contrast, well-trained children did not show significant differences in NT performance scores across the quartiles, suggesting that the advantages typically associated with being older within a given age group were lost, either through their regular training in soccer or rugby or because it is an inherent trait of higher performing athletes. This is inconsistent with previous research on the influence of age and skill level on the prevalence of the RAE in adult and youth football, which reported that the RAE became more pronounced as skill level increased in youth players.[32] However, the results of the present study are consistent with what has been described in a recent review on RAE in youth and elite soccer,[33] which concluded that there was no significant RAE in elite soccer teams due physical advantages not existing in older players. A similar view was expressed by Bäumler[18] in a study of professional adult football players in Germany, in which the RAE decreased with increasing age among players. One possible explanation for this finding is that intensive sports training can "level the playing field" by enhancing the physical, technical, and cognitive abilities of younger athletes, thereby compensating for the initial disadvantages of relative age. Consequently, younger players within a cohort may narrow the performance gap to their older peers, reducing the impact of RAE on their overall development. These results underscore the importance of providing equal training opportunities to all athletes, regardless of their birth quartile, as this can help to counteract the natural disadvantages associated with relative age. Coaches and sports organizations should prioritize training programs that focus on perceptual-cognitive skill development for younger players within age-group teams, ensuring that all athletes can reach their full potential.

It is important to recognize that there was significant variability in perceptual-cognitive skill within each group in the present study. This interindividual variability suggests that some players may possess naturally higher perceptual-cognitive abilities, regardless of their relative age. Understanding these differences could be important for talent identification and the formulation of athlete development programs, particularly in mitigating the effects of RAE. By identifying players with early high or low perceptual-cognitive skill, training programs can be tailored to develop these abilities effectively, promoting long-term athlete development and ensuring that talent is recognized beyond just physical maturity.[34]

Strengths and Limitations

One limitation of the present study is that differences in youth players' biological maturity may have influenced the findings.[35] While relative and biological ages are often linked in talent development, they should be considered separately.[36] Future research should address the respective influences of relative versus biological ages on the development of perceptual-cognitive skills to provide more accurate insights for long-term athlete development. Another limitation of the present study is that we did not study the relationship between NT scores and sports performance. While previous research has demonstrated that athletes with high NT performance scores may possess advanced perceptual-cognitive skills and sports performance, these studies primarily involved adults[15,37] rather than children and adolescents. Therefore, research is required to better understand the link between perceptual-cognitive skills and sports performance from childhood into adolescence. In addition, only male children and adolescents were studied. To date, limited research has investigated females from childhood to adolescence using the 3D-MOT task, despite findings indicating that male athletes may exhibit superior perceptual-cognitive skills in late adolescence.[38,39] Moreover, Roudaia and Faubert[40] highlighted that sex differences in perceptual-cognitive function, as assessed through MOT tasks, persist throughout aging, with untrained males demonstrating better performance than untrained females. These findings underscore the need for further research incorporating female participants to explore the potential concurrent effects of sex and relative age on perceptual-cognitive skills and their impact on sports performance, particularly in women's team sports.

A major strength of the present study is that, for the first time, we considered relative age rather than chronological age to specifically investigate the development of perceptual-cognitive skills, notably among a large age range around the adolescent growth spurt (10–16 y old). The present study provides important scientific evidence on how relative age with respect to stereopsis and training background influences the development of perceptual-cognitive skills. These findings are particularly significant when considering the number of children and adolescents playing team sports such as rugby and soccer, where decision-making skills are crucial for both individual and team performances. These results have important implications for long-term athlete development and talent identification.

Practical Applications

Moderately trained children born during the first 3 birth quartiles in a year outperformed their peers born later in year (last birth quartile), whereas well-trained children showed no differences between birth quartiles. In addition, well-trained children born in the last birth quartile performed similarly to moderately trained children born in the first 3 quartiles, suggesting that training background may offset the disadvantage associated with RAE from childhood into adolescence. Taken together, the present data improve our understanding of how training background may offset the RAE on perceptual-cognitive skills during childhood and adolescence, which is crucial for talent identification and long-term athlete development. These findings emphasize the need for a more flexible age-group classification system that takes into account relative age, biological age, and training age. Implementing diverse and adaptable game-based training programs can help reduce performance differences arising from disparities in these factors.[41]

Conclusions

RAE showed a significant disadvantage on the perceptual-cognitive performance scores in moderately trained children born in BQ_4. However, well-trained children born in BQ_4 performed similarly to other well-trained children and to moderately trained children born in the first 3 birth quartiles, meaning that training background may offset the disadvantage associated with RAE from childhood into adolescence.

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