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Examination of the Relative Age Effect on Physical and Tennis Performance in Competitive Tennis Players

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Abstract

The purpose of this study was to examine whether the physical characteristics, motor performance, and perceived exertion levels of licensed tennis players aged 10–11 differ according to birth quarters, and to determine the influence of the Relative Age Effect (RAE) on tennis performance. The study focused on how biological maturity differences between early- and late-born athletes are reflected in agility, technical skill, and endurance. Height, body weight, and body mass index were measured, and motor performance was assessed using the Hewitt Test and the Hit and Turn Test. Perceived exertion was evaluated with the Borg Scale. Anthropometric data were classified according to World Health Organization percentile standards. After confirming normality and homogeneity, independent samples t-tests, one-way ANOVA (Tukey post-hoc), and multiple regression analyses were conducted. Birth quarter was treated as the independent variable, and performance measures as dependent variables. Results showed that athletes born in earlier quarters performed significantly better, especially in agility-based tasks, while those born in later quarters exhibited lower performance and higher perceived exertion. Regression analyses supported these findings. Overall, the study demonstrates that RAE significantly affects tennis performance both physically and perceptually, highlighting the importance of considering developmental differences in training and talent selection.

Rekabetçi Tenis Oyuncularında Göreli Yaş Etkisinin Fiziksel ve Tenis Performansı Üzerindeki Etkisinin İncelenmesi

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Özet

Bu çalışma, 10–11 yaş aralığındaki lisanslı tenisçilerin fiziksel özellikleri, motor performansları ve algılanan efor düzeylerinin doğum çeyreklerine göre farklılaşıp farklılaşmadığını belirlemeyi ve bağıl yaş etkisinin (RAE) tenis performansı üzerindeki etkilerini ortaya koymayı amaçlamaktadır. Çalışmada özellikle erken ve geç doğan çocuklar arasındaki biyolojik olgunluk farklılıklarının çeviklik, teknik beceri ve dayanıklılık gibi performans bileşenlerine nasıl yansıdığı incelenmiştir. Araştırma kapsamında sporcuların boy, vücut ağırlığı ve vücut kitle indeksi ölçümleri alınmıştır. Motor performans değerlendirmesinde Hewitt testi (teknik isabet), Hit and Turn testi (çeviklik ve dayanıklılık) kullanılmış, algılanan efor düzeyi ise Borg Skalası ile belirlenmiştir. Antropometrik veriler Dünya Sağlık Örgütü persentil standartlarına göre sınıflandırılmıştır. Normallik ve homojenlik varsayımlarının sağlanmasının ardından bağımsız örneklem t-testi, tek yönlü ANOVA (Tukey post-hoc) ve çoklu regresyon analizleri uygulanmıştır. Doğum çeyreği bağımsız değişken, performans ölçümleri ise bağımlı değişkenler olarak ele alınmıştır. Sonuçlar, yılın erken döneminde doğan sporcuların özellikle çeviklik ve yön değiştirme gerektiren performanslarda daha başarılı olduğunu göstermiştir. Geç doğan sporcular ise daha düşük performans ve daha yüksek algılanan efor düzeyleri bildirmiştir. Bulgular, bağıl yaş etkisinin tenis performansını anlamlı biçimde etkilediğini ortaya koymaktadır.

1. INTRODUCTION

The developmental trajectories of physical, motor, and cognitive capacities do not progress uniformly throughout childhood and adolescence, leading to notable inter-individual differences in performance even among children of the same chronological age. This phenomenon, commonly referred to as the Relative Age Effect (RAE), reflects the influence of birth-date distribution within a selection year on athletic performance, selection likelihood, and long-term sport participation (Musch & Grondin, 2001; Cobley et al., 2009). Athletes born earlier in the calendar year are often characterized by more advanced biological maturation, superior motor proficiency, and greater psychological readiness compared to their later-born counterparts.

Such developmental disparities become particularly salient during critical growth periods, especially between the ages of 9 and 14, when both somatic and neuromuscular development accelerate (Malina et al., 2015). Even marginal differences in strength, coordination, agility, and reaction time may translate into meaningful advantages in skill acquisition and competitive performance. Consequently, early-born athletes tend to benefit disproportionately from these maturational advantages, whereas late-born individuals may experience relative developmental constraints that can hinder performance outcomes.

Tennis, as a complex and multidimensional sport, requires the integration of physical attributes (e.g., speed, strength, and endurance), technical competencies (e.g., stroke accuracy and ball control), and cognitive processes (e.g., anticipation and decision-making). Owing to these multifaceted demands, tennis provides a particularly suitable context for examining the implications of the Relative Age Effect. Existing literature in this domain has predominantly focused on selection patterns and ranking distributions, with comparatively limited attention given to the direct association between relative age and performance-related variables (Söğüt, 2023). However, given that even a few months' age difference may yield measurable discrepancies in agility, coordination, and reaction speed, it is imperative to explore how RAE manifests in actual performance contexts (Ferrauti et al., 2011; Baker et al., 2010).

Beyond physical and technical components, perceived exertion constitutes a critical dimension for understanding the psychophysiological implications of RAE. Perceived exertion, commonly assessed via the Borg Scale, reflects an individual's subjective evaluation of physical effort during exercise (Borg, 1982). Notably, identical physical demands may be perceived as less strenuous by early-born athletes and more demanding by their later-born peers. This discrepancy can be attributed not only to differences in physiological capacity but also to psychological factors such as self-confidence, motivation, and competitive anxiety (Robertson & Noble, 1997; Delorme et al., 2011). Accordingly, RAE should be considered a multidimensional construct encompassing both physical performance and perceptual responses.

The present study aimed to investigate whether physical characteristics, motor performance, and perceived exertion levels of licensed tennis players aged 10–11 vary according to birth quarter, and to determine the extent to which RAE influences tennis performance. More specifically, the study examined how differences in biological maturity between early- and late-born athletes are reflected in key performance domains, including agility, technical accuracy, and endurance.

Within the methodological framework, the sample consisted of male and female licensed tennis players aged 10–11. Anthropometric assessments, including height, body mass, and body mass index (BMI), were conducted to evaluate physical characteristics. Motor performance was assessed using the Hewitt Test, which measures technical accuracy, and the Hit and Turn Test, which evaluates agility and endurance capacity. Perceived exertion was quantified using the Borg Scale (Borg, 1982). Anthropometric data were further categorized in accordance with World

Health Organization percentile standards to ensure standardized interpretation of growth and development patterns.

Prior to inferential analyses, assumptions of normality and homogeneity of variance were verified. Independent samples t-tests were employed for pairwise comparisons, while one-way analysis of variance (ANOVA) with Tukey post-hoc procedures was utilized to examine differences across birth quarters. Additionally, multiple regression analyses were conducted to assess the predictive contribution of birth quarter to performance outcomes. In this analytical framework, birth quarter was treated as the independent variable, whereas motor performance indicators and perceived exertion levels were considered dependent variables.

The findings demonstrated that athletes born in the earlier quarters of the year exhibited significantly superior performance, particularly in agility-related tasks such as the Hit and Turn Test. These athletes showed enhanced movement efficiency and change-of-direction ability, both of which are critical determinants of tennis performance. Conversely, athletes born in the third and fourth quarters displayed comparatively lower performance levels. Regression analyses further confirmed that birth quarter constituted a significant predictor of motor performance outcomes.

In addition, late-born athletes reported higher levels of perceived exertion, indicating that physiological differences associated with biological maturity are also reflected in subjective exercise responses. This suggests that later-born individuals may perceive equivalent physical demands as more taxing, which may negatively influence their motivation and performance over time. These findings are consistent with previous research highlighting the dual impact of RAE on both physical performance and psychological experiences in sport (Delorme & Raspaud, 2009; Baker et al., 2018).

The implications of these findings are substantial for athlete development, training design, and talent identification processes. The systematic advantage observed among early-born athletes, coupled with the disadvantages experienced by late-born athletes, may contribute to inequities in sport participation and progression. Over time, these disparities may result in decreased motivation, reduced performance, and increased dropout rates among later-born individuals. This underscores the necessity of incorporating considerations of biological maturity and relative age into youth sport systems.

Furthermore, the Relative Age Effect should be examined not only from a physical performance perspective but also in relation to psychological and cognitive dimensions. Late-born athletes may develop lower self-confidence and experience heightened levels of stress and perceived effort, which can adversely affect their long-term engagement in sport. Therefore, the implementation of equitable and developmentally informed training and competition structures is essential to mitigate the negative consequences of RAE.

In conclusion, tennis performance is contingent upon a range of interrelated factors, including agility, reaction speed, endurance, and concentration, in addition to technical proficiency. However, the development of these attributes is more closely associated with biological maturity than chronological age. Even a 10–12 month difference in birth date within the same age cohort can lead to substantial performance disparities. Consequently, acknowledging and addressing the Relative Age Effect is critical for ensuring fairness in talent identification, optimizing athlete development pathways, and promoting sustained participation in sport.

2. METHOD

2.1. Research Design

The study's research design is based on a quantitative research framework and includes elements of both causal-comparative (ex post facto) and correlational survey approaches. The main aim of this investigation is to assess the impact of developmental factors, including age, gender, birth half, birth quarter, and body composition, on the performance and perceived effort of young tennis players, without the application of any experimental intervention. Consequently, the study employs a descriptive format that focuses on comparing naturally occurring groups and evaluating the relationships between various variables.

The causal-comparative research model involves a quantitative approach in which the researcher does not manipulate the independent variables but instead explores the potential causes of the observed differences in pre-existing groups. In this model, groups are naturally established prior to the research, and the researcher statistically analyzes the differences between these groups (Karasar, 2016).

The main goal of causal-comparative research is not to establish clear cause-and-effect relationships but to describe the differences found among groups that possess certain characteristics and to investigate the variables that may relate to these differences. Thus, this approach diverges from experimental designs and is characterized by its descriptive nature (Karasar, 2016).

Büyüköztürk et al. (2022) point out that the causal-comparative model is often favored in circumstances where experimental manipulation cannot be performed due to ethical, practical, or technical reasons. Variables like age, gender, birth timing, biological traits, and individual differences are not amenable to experimental control; hence, this model serves as an important methodological alternative in such situations.

While assessing the statistical significance of the differences noted among groups, the outcomes from causal-comparative studies ought not to be seen as definitive cause-and-effect relationships. Rather, the results should be analyzed within the context of potential influences and connections. Accordingly, although careful interpretation of the results is necessary, causal-comparative research is acknowledged as a robust method for evaluating existing conditions (Büyüköztürk et al., 2022). In the correlational survey aspect of the research, the direction and intensity of relationships among the variables were assessed. Specifically, the associations among age, birth quarter, body mass index, and performance test results were scrutinized. The correlational survey framework does not seek to establish causal relationships but instead aims to outline patterns of co-variation and statistical correlations among the variables (Karasar, 2016).

2.2. Participants

This research was carried out with male and female competitive tennis players aged 10 to 11 who are actively participating in tennis in Türkiye. A total of 86 participants (40 females and 46 males) were selected, all of whom consistently train at ENKA Sports Club and have held tennis licenses for at least five years.

The selection criteria were formulated to align with the study's objectives and to ensure participant uniformity. Thus, athletes included were aged 10 to 11 years, had been practicing tennis regularly for at least five years, possessed no prior history of injuries, musculoskeletal disorders, or metabolic diseases, and willingly consented to participate in the study.

Athletes who did not fulfill the outlined criteria or were considered incapable of completing the testing procedures due to health issues were excluded from the study. This approach ensured

that the sample displayed comparable traits regarding both health status and levels of performance.

2.3. Data Collection Tools

2.3.1 Anthropometric Measurements

Data collection instruments were chosen based on the study's aims, and all evaluations were performed in line with standardized scientific methods. Anthropometric factors, such as height and weight, along with measures related to performance, were assessed using trustworthy and globally recognized techniques. The gathering of anthropometric data followed established protocols as detailed in the Anthropometric Reference Manual (Heath & Carter, 1967), which ensured both accuracy and consistency in the measurements.

Height was recorded with participants upright and barefoot in an anatomical stance, ensuring that their heels were together and their heads were positioned in alignment with the Frankfort plane. Measurements were taken using a Lafayette stadiometer that offers a precision of 0.1 cm, and results were documented to the nearest decimal. Body weight was measured via a calibrated Tanita body composition analyzer (Tanita 780MA, Tokyo, Japan), with participants donning light athletic attire and no footwear. The precision for weight measurements was set at 0.1 kg.

Body Mass Index (BMI) was computed by taking the body weight in kilograms and dividing it by the height in meters squared (m^2). Since the sample was composed of children and adolescents, BMI values were analyzed based on age- and sex-specific standards instead of being regarded as absolute measures (WHO, 2007; CDC, 2000). BMI was evaluated as a continuous variable, and its correlation with performance variables was examined within the framework of growth and developmental stages.

2.3.2 Hewitt Test

To assess the tennis abilities of the participants, the Hewitt Tennis Skill Test was implemented. The Hewitt Test serves as a commonly utilized performance evaluation that aims to assess accuracy in ball placement, precision, and mastery of strokes among tennis players. This test was performed following the protocols originally specified in the Hewitt Tennis Achievement Test as outlined by Hewitt in 1966.

In the course of the evaluation, a rope was horizontally positioned at a height of 2.10 meters above the court floor, thus establishing a target area between the rope and the tennis net. Participants were instructed to propel the ball through this designated area and ensure it landed within specific target zones on the opposite side of the court. Each participant executed a total of 20 strokes, comprising 10 forehand and 10 backhand hits.

The scoring system was based on where the ball first made contact on the opponent's court. The region located between the service line and the baseline was divided into five equal sections, each measuring 110 centimeters. Shots that landed nearest to the service line were awarded 1 point, with the points escalating (2, 3, 4, and 5) as the landing area moved towards the baseline. The maximum score of 5 points was granted when the ball landed in the zone closest to the baseline. Shots that successfully navigated through the target space and landed in the highest scoring zone were deemed optimal.

The following instances were designated as scoring 0 points

* The ball landed outside the boundaries of the court.
* The ball struck the net or was not successfully cleared.
* The ball bounced twice prior to reaching the target area.
* The ball landed outside the specified scoring zones.

Each stroke was assessed independently, and overall scores were computed by totaling the points associated with each shot. The final score functioned as a quantitative measure of the participants' accuracy and control skills concerning both forehand and backhand strokes.

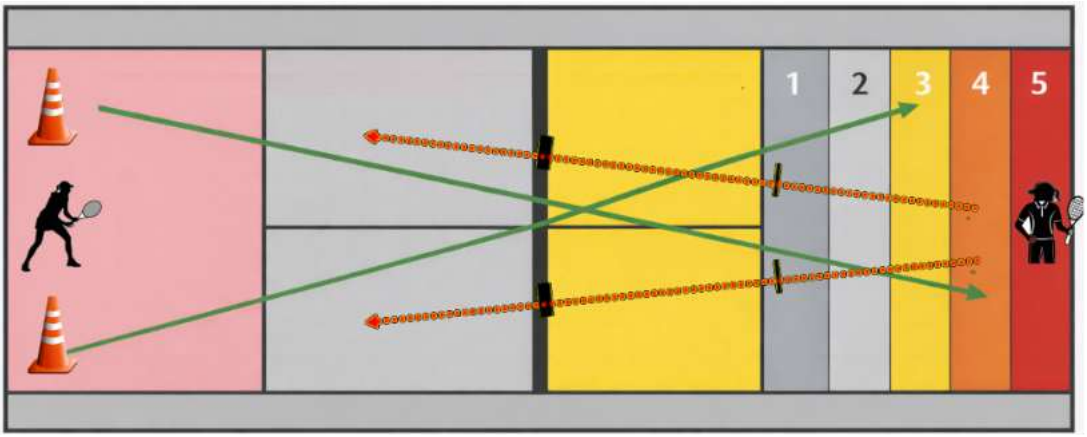

Figure 1 Hewitt Test (1966)

2.3.3 Hit and Turn Test

The Hit–Turn Test was conducted to assess tennis players' physical endurance, mobility, and ability to change direction on the court. This assessment is a field test tailored to the sport, created to evaluate multidirectional movement capabilities and the ability to maintain performance during repeated strokes in tennis.

During the assessment, participants began from a ready stance on the baseline and executed forehand and backhand strokes while moving laterally to both the left and right within the doubles court lines. The directions for movement and the timing were prompted by auditory cues given throughout the test, requiring participants to reach specified areas in response to these cues.

The Hit–Turn Test comprises 20 levels, each increasing the speed requirements progressively. The overall duration of the test spanned approximately 47 to 50 seconds, during which participants completed between 12 and 16 strokes. As the test continued, the intervals between the auditory signals were systematically shortened, decreasing from 4.9 seconds in the initial levels to 3.0 seconds in the final levels. This setup aimed to test both the athletes' endurance and their speed in reacting and changing direction.

The test was concluded if a participant failed to reach the target area within the allotted time, could not sustain the necessary movement pattern, or exhibited significant signs of fatigue. This procedure was overseen by a qualified coach, and performances were evaluated through direct observation. A rest period of 10 seconds was allowed between levels to facilitate safe and controlled test execution.

The implementation and structure of levels for the Hit–Turn Test adhered to standardized protocols established by Ferrauti (2011), which are intended to accurately represent the physiological and movement-related requirements of tennis.

2.3.4 Rate of Perceived Exertion (RPE) Scale

In conjunction with performance evaluations, the Borg Rating of Perceived Exertion (RPE) Scale was utilized to gauge the athletes' personal evaluations of their exertion during physical activity. The Borg Scale serves as a subjective assessment tool that spans from 6 to 20 and has

been found to have a strong correlation with physiological markers, such as heart rate, breathing rate, and muscle fatigue (Borg, 1982).

Nevertheless, since the participants of the study were children, the traditional Borg Scale, which was created for adults, may not adequately suit their cognitive levels. Consequently, the evaluation of perceived exertion was conducted using the OMNI Rating of Perceived Exertion (OMNI-RPE) Scale, which is tailored specifically for children and adolescents. This scale incorporates visual aids, simpler descriptions, and ratings that are appropriate for their age, which facilitates more precise self-reporting (Robertson et al., 2000).

Prior research has illustrated that OMNI-RPE scores have a significant connection with physiological data, offering a valid and dependable measurement of exercise intensity among younger populations (Utter et al., 2002).

2.4. Data Collection Procedures

All evaluations took place on outdoor hard courts at ENKA Sports Club in natural lighting during June 2025, with temperatures fluctuating between 26 and 29 degrees Celsius. The weather remained stable, characterized by a gentle breeze and no rainfall. To reduce the effects of fatigue, a minimum interval of two days was observed between the tennis skill assessments (Hewitt and Hit–Turn) and evaluations of perceived exertion.

Prior to testing, participants engaged in a standardized warm-up routine, and all sessions were organized at comparable times to mitigate variations in environmental factors. Tennis balls were consistently supplied by the same researcher to maintain uniformity. Identical equipment and court setups were utilized throughout all sessions, with oversight provided by a seasoned coach to bolster reliability and consistency in the procedures.

2.5. Data Analysis

Before conducting statistical analyses, the dataset underwent a thorough examination to confirm that all essential assumptions were satisfied. The normality of the data was evaluated through the use of histogram distributions, Q-Q plots, and descriptive statistics, including calculations of skewness and kurtosis. Variables that complied with the normality assumptions were subsequently analyzed utilizing parametric statistical techniques. The homogeneity of variances was assessed via Levene's test to ascertain the appropriateness of group comparisons.

To facilitate comparisons among groups, independent samples t-tests were utilized when examining two groups, while one-way analysis of variance (ANOVA) was applied for comparisons that included more than two groups. In instances where the results from ANOVA indicated statistically significant differences, Tukey HSD post-hoc tests were performed to pinpoint the specific groups contributing to these differences. Given the inadequate sample sizes in certain birth quarter categories for the 10-year-old participants, the birth quarters were restructured into two groups: the first half (January–June) and the second half (July–December), and analyzed through independent samples t-tests.

To enhance the power of the statistical analysis and complement the group-based comparisons, regression analyses were conducted. Linear regression models were used to explore the predictive effects of independent variables such as birth quarter, age, and body mass index (BMI) on performance outcomes, which included scores from the Hewitt and Hit–Turn tests. The categorical variable of birth quarter was integrated into the regression models employing dummy coding, which is considered a standard approach in quantitative research (Karasar, 2016; Büyüköztürk et al., 2022).

Moreover, the intra-rater reliability of the perceived exertion scores was assessed utilizing the intraclass correlation coefficient (ICC). The ICC(3,1) model (two-way mixed, consistency, single

measures) was implemented based on data gathered from 86 participants across four separate measurements. The calculated ICC value was low (. 20), suggesting variability among the repeated measures. However, this finding was interpreted not as a limitation in measurement but as an indication of the dynamic and load-sensitive characteristics of perceived exertion, which is anticipated to increase alongside the progression of exercise intensity (Borg, 1982).

A post-hoc power analysis was performed with the use of GPower 3.1 in order to assess whether the sample size was adequate for identifying differences between groups. With an assumed medium effect size (f = . 25), a significance level of α = . 05, and a statistical power of 80%, the necessary sample size was determined to be 64. The actual sample size utilized in the study was 86, which surpasses this minimum requirement, demonstrating that the study possessed enough statistical power to identify significant differences (Faul et al., 2007; Cohen, 1998). All statistical evaluations were conducted utilizing the Jamovi statistical software (version 2025).

2.6. Ethical Considerations

This study was conducted in accordance with academic ethical principles. Participation was voluntary, and informed consent was obtained from participants and their legal guardians. All data were anonymized, and no personal identifying information was collected. The procedures did not involve any risk or harm to participants, and all measurements were carried out under safe conditions. Additionally, proper citation and referencing practices were followed throughout the study, and all sources were used in compliance with academic integrity standards.

3. FINDINGS

This section presents the findings of the study examining the effects of birth quarter on physical characteristics, motor performance, and perceived exertion levels in 10–11-year-old tennis players. The results are organized according to the research variables and statistical analyses conducted, including group comparisons and regression analyses. The aim is to reveal how the Relative Age Effect (RAE) influences performance outcomes in young tennis athletes.

Table 1. Effect of Birth Quarter on Hewitt Test in 10-Year-Old Athletes

Predictor Variable	B	SE	t	p
Intercept (First Quarter)	50.17	2.91	17.241	< .001
Second Quarter – First Quarter	-3.47	4.04	-0.861	.395
Third Quarter – First Quarter	-12.26	4.21	-2.913	.006
Fourth Quarter – First Quarter	-14.50	6.51	-2.229	.032

Based on the findings from the regression analysis that investigated the impact of birth quarter on the performance in the Hewitt test among 10-year-old athletes, children born in the first quarter were designated as the reference cohort. The Hewitt test performance average for children born in the first quarter was calculated to be 50.17 points, a figure deemed statistically significant. An examination of the second-quarter-born children revealed no noteworthy difference when compared to their first-quarter counterparts; while their average performance was roughly 3.47 points lower, this disparity did not reach statistical significance.

In contrast, those born in the third quarter showed a statistically significant decrease of 12.26 points relative to the first-quarter group. Likewise, the Hewitt test scores for children born in the fourth quarter were 14.50 points lower than those of the first quarter, a difference that also achieved statistical significance.

In summary, the results reveal that performance on the Hewitt test declines significantly as the birth quarter advances. Specifically, children born in the third and fourth quarters demonstrate poorer performance compared to their first-quarter-born peers. These findings indicate that the Relative Age Effect is a crucial factor influencing agility-related performance outcomes.

Table 2. Effect of Birth Quarter on Hit and Turn Test in 10-Year-Old Athletes

Predictor Variable	B	SE	t	p
Intercept (First Quarter)	58.20	4.26	13.65	< .001
Second Quarter – First Quarter	-18.60	5.91	-3.15	.003
Third Quarter – First Quarter	-13.30	6.16	-2.15	.038
Fourth Quarter – First Quarter	-20.50	9.53	-2.15	.038

The findings from the regression analysis exploring the impact of birth quarter on the performance of the Hit and Turn test among 10-year-old athletes reveal that children born in the first quarter served as the benchmark group. Consequently, the mean performance score for athletes born in the first quarter was recorded at 58.2 points, and this figure was deemed to be significantly noteworthy. Athletes born in the second quarter showed a performance level that was 18.6 points below that of their first-quarter counterparts, with this disparity being statistically significant. Likewise, athletes born in the third quarter exhibited a reduction of 13.3 points in performance, which was also found to be statistically significant. Additionally, the performance of those born in the fourth quarter was 20.5 points lower when compared to the first-quarter group, and this difference was similarly statistically significant.

These results suggest that the performance on the Hit and Turn test declines progressively as one moves to later birth quarters. Specifically, athletes who are born in the second, third, and fourth quarters demonstrate diminished levels of endurance and performance in contrast to those born in the first quarter. The outcomes illustrate that the Relative Age Effect significantly impacts measures related to endurance performance as well.

Table 3. Effect of Birth Quarter on Hewitt Test in 11-Year-Old Athlete

Predictor Variable	B	SE	t	p
Intercept (First Quarter)	41.50	2.95	14.07	< .001
Second Quarter – First Quarter	0.12	4.25	0.03	.978
Third Quarter – First Quarter	-1.00	4.57	-0.22	.828
Fourth Quarter – First Quarter	-7.70	4.57	-1.68	.099

The findings of the regression analysis that explored the impact of birth quarter on the performance of the Hewitt test among 11-year-old athletes reveal that those born in the first quarter served as the baseline group. The average score for the Hewitt test among athletes born in the first quarter was determined to be 41.50, a figure that was regarded as highly significant. Athletes born in the second quarter showed a performance level that was almost equivalent to that of the first quarter, with a minor increase of only 0.12 points; this variation lacked statistical significance.

In comparison, athletes born in the third quarter experienced a decline in performance by 1 point relative to the first-quarter cohort; nonetheless, this change also did not achieve statistical significance. Athletes born in the fourth quarter displayed a reduction of approximately 7.7 points. While this difference came close to statistical significance (p = . 099), it ultimately did not meet the standard threshold for significance.

In summary, birth quarter does not significantly influence the Hewitt test performance within the 11-year-old cohort. However, the trend of relatively lower performance among athletes born in the fourth quarter may be regarded as an important observation.

Table 4. Effect of Birth Quarter on Hit and Turn Test in 11-Year-Old Athletes

Predictor Variable	B	SE	t	p
Intercept (First Quarter)	66.36	4.38	15.15	< .001
Second Quarter – First Quarter	7.49	6.31	1.19	.242
Third Quarter – First Quarter	-20.06	6.78	-2.96	.005
Fourth Quarter – First Quarter	-12.16	6.78	-1.79	.080

Based on the findings from the regression analysis that explored how birth quarter impacts performance on the Hit and Turn test among 11-year-old athletes, those born in the first quarter served as the reference cohort, achieving a mean score of 66.36, which was statistically significant. In comparison, athletes born in the second quarter scored about 7.5 points higher than their first-quarter counterparts; however, this discrepancy was not found to be statistically significant.

In contrast, athletes born in the third quarter experienced a significant reduction in performance, achieving 20.06 points fewer than the first-quarter athletes, with this difference being statistically significant (p = . 005). Athletes born in the fourth quarter also displayed a decline in performance, scoring approximately 12.16 points lower than those born in the first quarter; yet, while this difference approached statistical significance (p = .080), it did not meet the standard criteria.

Overall, the analysis reveals that the birth quarter has an adverse effect on performance in the Hit and Turn test, especially for athletes who were born in the third quarter. A similar trend of decreased performance was noted among fourth-quarter-born athletes, but this difference was not statistically significant. These findings imply that the Relative Age Effect may lead to a substantial performance disadvantage, particularly for athletes born in the mid-year months.

4. CONCLUSION

In this research, the impact of the Relative Age Effect (RAE) on the performance of young tennis players was analyzed, specifically focusing on regression analyses that consider differences based on the quarter of birth. The results indicated that variations in development related to the timing of birth significantly influence both agility and endurance-related performance measures among athletes aged 10 and 11 years.

The regression analyses indicated that the RAE is particularly evident among 10-year-olds. The findings from the Hewitt test identified athletes born in the first quarter as the baseline group and they demonstrated the highest average performance. Conversely, as the birth quarter advanced, a considerable decline in performance was noted. Athletes born in the third and fourth quarters indicated decreases of about 12 and 14 points, respectively, with these variances being statistically significant. This suggests that the RAE substantially influences performance in tasks requiring agility and technical skills.

A similar trend was more distinctly observed in the results from the Hit and Turn test. Among the 10-year-old participants, those born in the first quarter recorded the highest performance indicators, while athletes born in the second, third, and fourth quarters scored approximately 18, 13, and 20 points lower, respectively, with all discrepancies being statistically significant. This implies that RAE has a considerable effect on neuromuscular performance aspects such as

endurance, speed, and the ability to change direction. Previous studies have also suggested that performance in agility and sprinting is closely related to biological maturity, wherein athletes born earlier in the year have a significant edge in these areas (Malina, Bouchard, & Bar-Or, 2015; Philippaerts et al., 2006).

The significant regression results in the group aged ten reinforce the idea that the relative age effect (RAE) is most evident in early childhood and early adolescence. In this particular age group, variations in development ranging from 9 to 12 months can lead to significant advantages in attributes such as muscle strength, coordination, and reaction time (Musch & Grondin, 2001; Cobley et al., 2009). Thus, it is anticipated that athletes born earlier in the year will show enhanced performance in the Hewitt and Hit and Turn assessments.

Regression analyses performed on the group of eleven-year-olds indicate that while the impact of RAE lessens somewhat, it does not entirely vanish. In the Hewitt assessment, the birth quarter did not show a statistically significant effect on performance levels. There were no notable differences between athletes born in the first quarter compared to those in the second and third quarters; however, athletes born in the fourth quarter displayed lower performance levels that were close to, but not quite at, the level of statistical significance. This implies that as individuals age, the influence of training and experience on technical skills becomes increasingly pronounced (Williams & Ford, 2008).

Conversely, the outcomes from the Hit and Turn test for the eleven-year-old group unequivocally indicate that RAE continues to impact performance. Athletes born in the third quarter performed approximately 20 points lower compared to those from the first quarter, and this disparity was statistically significant. A similar decreasing pattern was noted among athletes born in the fourth quarter, though this difference still lay at a borderline level of significance. These observations suggest that although differences in biological maturity start to even out with age, RAE still plays a role in influencing neuromuscular performance attributes such as agility and endurance.

Overall, the regression analysis presents a notable difference in the outcomes of the Hewitt and Hit and Turn tests. The Hit and Turn test, which evaluates agility, speed, and the ability to change direction, seems to be more significantly affected by the Relative Age Effect (RAE). Conversely, the Hewitt test, which centers on the precision of technique and positioning of the ball, exhibits weaker or negligible impacts from the birth quarter. This difference implies that aspects of physical performance are more responsive to variances in biological maturity, while technical abilities are more closely tied to the processes of training experience and skill development (Ferrauti et al., 2011; Fernandez-Fernandez et al., 2014).

Perceived exertion, as measured by the Borg Scale, was analyzed as a secondary factor in this investigation. The results indicate that athletes born later in the year generally report greater levels of perceived exertion while undergoing identical physical demands. This finding implies that RAE influences not only quantitative performance metrics but also psychophysiological reactions (Robertson & Noble, 1997). Nonetheless, because the primary aim of the regression analysis was to assess performance metrics, the results from the Borg scale were regarded as supplementary rather than primary findings.

In summary, the regression analyses indicate that the Relative Age Effect significantly influences performance among the 10-year-old participants and exhibits a moderate yet consistent impact in the 11-year-old cohort. While the influence of birth quarter is minimal in the Hewitt test, it is distinctly significant and clearly observable in the Hit and Turn test. These outcomes underscore that RAE is a crucial factor, especially concerning physical performance elements such as agility, speed, and endurance.

Thus, it is crucial to take into account not just chronological age but also the quarter of birth and biological maturity when assessing young athletes. Failing to do so may result in early-born athletes consistently receiving advantages, while those born later may experience disadvantages in performance and development. These differences could create biases in the processes of identifying talent and developing athletes. Therefore, training programs and evaluation frameworks must be designed to consider these developmental variances to promote equity and enhance the long-term development of athletes.

Recommendations

Strategies ought to be established to address the imbalance associated with birth quarters in the selection processes for athletes. It is crucial for organizations to guarantee equitable representation and enhance understanding of the Relative Age Effect (RAE) among coaches and educators. Training initiatives must focus on personalization, allowing for more intense and technique-centered training for athletes born earlier in the year, while offering encouraging, confidence-enhancing, and skill-oriented methodologies for those born later. Subjective levels of exertion should be assessed using suitable scales (e.g., Borg, OMNI) to tailor training loads to the individual's needs. Furthermore, psychological aspects such as motivation and self-esteem must be nurtured, especially for athletes born later in the year. For individuals with excess weight, low-impact, game-oriented activities are advisable. Continuous monitoring and future studies concerning bio-banding and RAE in various settings are vital.

Conflict of Interest

The author(s) declare that there is no conflict of interest related to this study.

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5. REFERENCES

Baker, J., Schorer, J., & Cobley, S. (2010). Relative age effects: An inevitable consequence of elite sport? Sportwissenschaft, *40*(1), 26–30. https://doi.org/10.1007/s12662-009-0095-2

Baker, J., Schorer, J., & Wattie, N. (2018). Compromising talent: Issues in identifying and selecting talent in sport. Quest, *70*(1), 48–63. https://doi.org/10.1080/00336297.2017.1333438

Borg, G. A. V. (1982). Psychophysical bases of perceived exertion. Medicine & Science in Sports & Exercise, *14*(5), 377–381. https://doi.org/10.1249/00005768-198205000-00012

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2022). Eğitimde bilimsel araştırma yöntemleri (28. baskı). Pegem Akademi.

Cobley, S., Baker, J., Wattie, N., & McKenna, J. (2009). Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. Sports Medicine, *39*(3), 235–256. https://doi.org/10.2165/00007256-200939030-00005

Delorme, N., & Raspaud, M. (2009). The relative age effect in young French basketball players: A study on the whole population. Scandinavian Journal of Medicine & Science in Sports, *19*(2), 235–242. https://doi.org/10.1111/j.1600-0838.2008.00781.x

Delorme, N., Chalabaev, A., & Raspaud, M. (2011). Relative age is associated with sport dropout: Evidence from youth categories of French basketball. Scandinavian Journal of Medicine & Science in Sports, *21*(1), 120–128. https://doi.org/10.1111/j.1600-0838.2009.01060.x

Fernandez-Fernandez, J., Sanz-Rivas, D., Sanchez-Muñoz, C., Pluim, B. M., Tiemessen, I., & Mendez-Villanueva, A. (2014). A comparison of the activity profile and physiological demands between advanced and recreational veteran tennis players. Journal of Strength and Conditioning Research, *28*(6), 1656–1663. https://doi.org/10.1519/JSC.0000000000000305

Ferrauti, A., Kinner, V., & Fernandez-Fernandez, J. (2011). The Hit & Turn Tennis Test: An acoustically controlled endurance test for tennis players. Journal of Sports Sciences, *29*(5), 485–494. https://doi.org/10.1080/02640414.2010.546424

Karasar, N. (2016). Bilimsel araştırma yöntemi (31. baskı). Nobel Yayın Dağıtım.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). Growth, maturation, and physical activity (2nd ed.). Human Kinetics.

Malina, R. M., Rogol, A. D., & Coelho e Silva, M. J. (2015). Biological maturation of youth athletes: Assessment and implications. British Journal of Sports Medicine, *49*(13), 852–859. https://doi.org/10.1136/bjsports-2015-094623

Musch, J., & Grondin, S. (2001). Unequal competition as an impediment to personal development: A review of the relative age effect in sport. Developmental Review, *21*(2), 147–167. https://doi.org/10.1006/drev.2000.0516

Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., Bourgois, J., Vrijens, J., Beunen, G., & Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. Journal of Sports Sciences, *24*(3), 221–230. https://doi.org/10.1080/02640410500189371

Robertson, R. J., & Noble, B. J. (1997). Perception of physical exertion: Methods, mediators, and applications. In J. O. Holloszy (Ed.), Exercise and sport sciences reviews (Vol. 25, pp. 407–452). Williams & Wilkins.

Robertson, R. J., Goss, F. L., Dube, J., Rutkowski, J., Dupain, M., Brennan, C., & Andreacci, J. (2000). Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. Medicine & Science in Sports & Exercise, *32*(5), 965–971. https://doi.org/10.1097/00005768-200005000-00013

Söğüt, M. (2023). Relative age effect in tennis: A systematic review. International Journal of Sports Science & Coaching, *18*(1), 220–232. https://doi.org/10.1177/17479541221113433

Utter, A. C., Robertson, R. J., Green, J. M., Suminski, R. R., McAnulty, S. R., & Nieman, D. C. (2002). Validation of the adult OMNI scale of perceived exertion for walking/running exercise. Medicine & Science in Sports & Exercise, *34*(11), 1776–1780. https://doi.org/10.1097/00005768-200211000-00015

Williams, A. M., & Ford, P. R. (2008). Expertise and expert performance in sport. International Review of Sport and Exercise Psychology, *1*(1), 4–18. https://doi.org/10.1080/17509840701836867