

Article

Early Bloomer and Future Master: Getting to the Top of the Modern Badminton World

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Abstract: The road to the top is never easy. This study investigated whether the career trajectories of top-level men's and women's badminton players could be predicted by their age at first major debut and the time taken to reach the top 150. Data from the BWF from October 2009 to October 2022 were analyzed using a predictive linear regression model with Bayesian inference, adjusting for anthropometric factors. The results suggested that age at debut influences career high rankings among over 120 elite players. Additionally, observations challenged the Matthew effect in early-career success for young players, proposing that inherent talent may be more significant than early nurturing. The study also examined the potential impact of relative age and early specialization in sports.

Keywords: badminton; sports science; career trajectory; success; debut



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1. Introduction

Predictive human behavior has been a keen interest among researchers. We often see exceptional human behavior at the Olympics; badminton represents an ideal model for testing exceptional human interceptive performance [1]. World rankings in any Olympic sport measure the relative success of professional players competing around the globe. There is no exception for the badminton world. The Badminton World Federation (BWF) has designed a ranking system to quantify the performance at the top level of badminton players. Being a professional badminton player is never easy, taking both physical power and mental prowess [2,3]. Talented players do their all to fully develop for stepping onto the world stage; it all starts from their first experience with badminton in a school or community program to eventual podium success. The BWF often views attaining a top 150 rank as a significant career milestone. Firstly, the BWF ranking system is based on a cumulative point system that considers the player's performance in top-level tournaments over the past 52 weeks. Therefore, a player's ranking is a reliable indicator of their current form and consistency. Secondly, the top 150 players in the BWF ranking represent a highly competitive group of players who have consistently demonstrated their ability to compete at the elite level. These players have usually earned a significant number of ranking points

by performing well in major international tournaments, such as the World Championships, the Olympic Games, and BWF World Tour events.

Moreover, the top 150 players generally have access to better training facilities, coaching, and sponsorship opportunities than those ranked below them, which can significantly impact their development and success in the sport. Finally, statistical analysis of BWF ranking data has shown that players who are ranked within the top 150 have a significantly higher chance of winning major international tournaments and achieving long-term success in the sport than those ranked outside the top 150 [4]. Hence, computational indexes can be formulated to identify which players who attained the top 150 are likely to reach the top. Many factors have been reported to be crucial for next-level performance in badminton games [5]. Nonetheless, the discussion of early talent and late bloomers in later success in athletic careers remains unsettled [6,7]. Given the enrichment history in badminton, we wonder if early talents could be much more likely to succeed in future competitions and ranking results.

A core science issue concerns developing a quantitative understanding of the evolution and impact of an individual's career [8]. Achieving professional goals requires a long-term career development plan and early preparation [9]. For example, significant work with scientific impact is often believed to be carried out early in players' careers [9,10]. Likewise, talented players require identification early to prepare, plan, and train in a given specialization sport. However, there is no quantitative evidence that training and specialization before puberty are necessary to increase the likelihood of success in attaining the elite level [10,11]. Therefore, we explore if the career progression of elite men's and women's singles badminton players can be predicted by the age of debut on the world stage and the time spent to make the top 150. Accordingly, the age of debut performance on the world stage is likely relevant to early specialization in sports [10,11], indicating the potential influence of pubertal development and psychological issues in defining early-career success. Moreover, a common phenomenon observed in youth sports is that players are often overrepresented by a group of athletes born in or around specific birth months; therefore, we wonder whether the relative age effect [12,13] could be observed. Specifically, our aim was to investigate the potential impact of the relative age effect on athlete performance using a large dataset. The relative age effect suggests that athletes born closer to the selection cut-off dates have a developmental advantage over their younger peers within the same age category, which could influence early selection and long-term development in sports.

In this study, we assessed whether the career progression of elite men's and women's singles badminton players could be predicted by the age of debut on the world stage and the time spent to make it to the top 150. We hypothesize that early career success could lead to prosperous career high rankings in elite badminton players. Specifically, promising performance delivered on the professional world stage at an early age could significantly impact its later achievement. However, the accomplishment can be attributed to early specialization in sports at a relatively young age. To this end, we investigate the association between these elite badminton players' age and birth month distribution concerning career ranking. If early specialization in sports could impact accomplishment later, we may observe the considerable proportion of athletes who made their top 150 debut impressions before puberty. Likewise, if relative age effects exist, we could observe the differences between the number of athletes in different birth months. We expect to collect publicly available datasets from the BWF to build a model through predictive analytics.

2. Materials and Methods

2.1. Data Collection and Description

The data were collected from the BWF official page (<https://bwfbadminton.com/rankings/> (accessed on 22 March 2022)). We extracted data and rank performances from 8 October 2009 to 4 October 2022 for every professional player submitted to the BWF's ranking system (a total of 35,509 players; see Figure 1) globally. The official data are only systematically

documented from 8 October 2009; no earlier data can be traced. To mitigate the potential relative age effects, we also collected birthdates through Wikipedia (<https://www.wikipedia.org/> (accessed on 31 March 2022)) and specifically extracted the birth months for every player who made it to the top 150 (see Figure 2). Of these 35,509 players, we excluded those who had just debuted within five years, because the tournament had been canceled for almost two years due to the COVID-19 pandemic. Therefore, there are no data from 2020. Furthermore, we included only those players who made the top 150 and ranked in the top 100 later. Only 128 remaining players (0.07% left-handed, female = 65) entered the subsequent analysis. Specifically, for women's singles players, only 20 made it to the top 30, 24 to the top 31–70, and 21 to the top 71–100. Meanwhile, for men's singles players, only 21 made it to the top 30, 21 to the top 31–70, and 21 to the top 71–100.

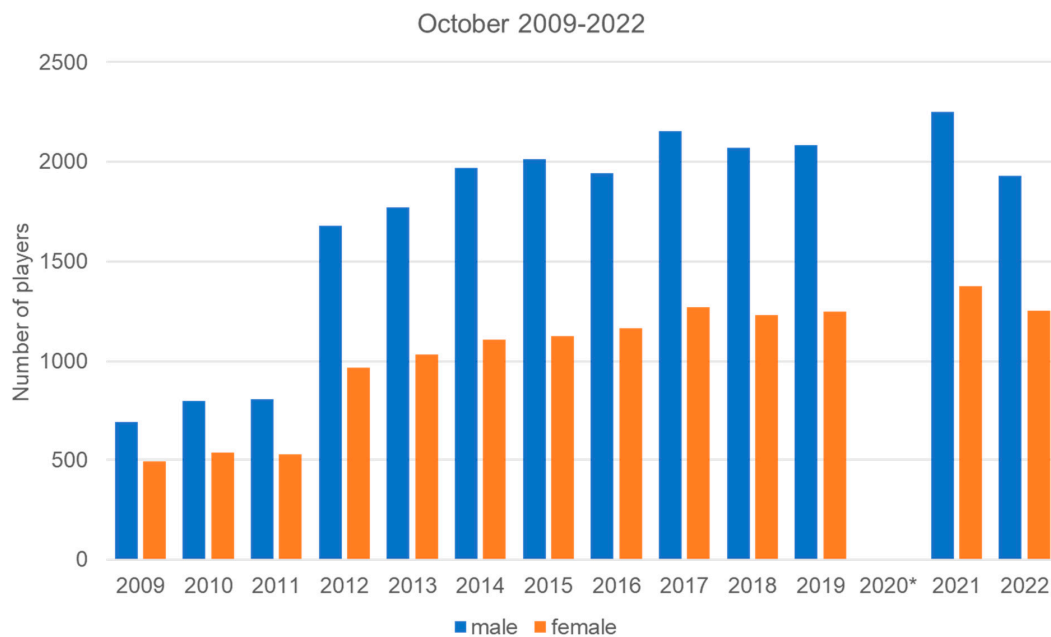


Figure 1. The number of professional players from 2009 to 2022. * denotes the absence of competition records for 2020 on the BWF official site, attributed to the COVID-19 pandemic.

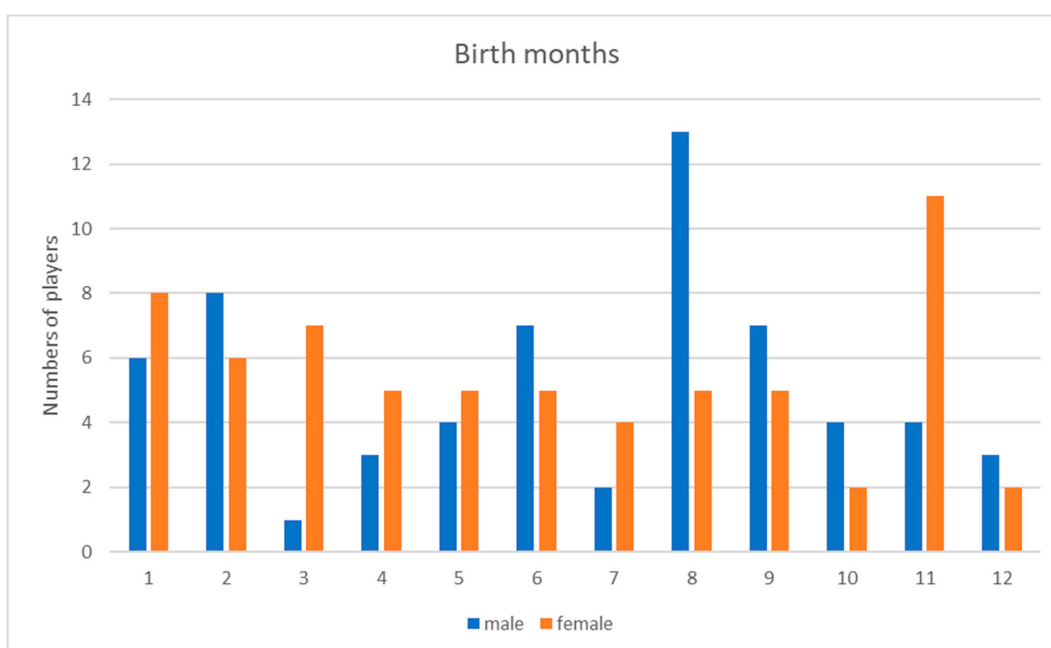


Figure 2. Birth month distribution across athletes.

Players earn ranking points by participating in and winning matches in tournaments. The higher the level of the tournament, the higher the number of ranking points that could be earned. The further a player progresses in competition, the more points are earned. The BWF determined that players who ranked within the top 150 could be minimally qualified to be invited to participate in tournaments. The tournament can be classified into three grades with different ranking points. The Olympics and World Championships are Grade 1 events. The Super Series (1000, 750, 500, 300, 100) and the World Tour Finals are Grade 2. Only players ranked up to 150 qualify to participate in the Grade 2 competition. Therefore, a player who made the top 150 is qualified to participate in the super100 event, the lowest qualification point competition for Grade 2. The other competitions like the International Challenge, International Series, and Future Series are Grade 3 (https://en.wikipedia.org/wiki/Badminton_World_Federation (accessed on 24 March 2022)). The obligations of the top 15, which are called “top committed player” obligations, are to attend all Super 1000 and 750 tournaments and at least 4 Super 500 tournaments, (<https://corporate.bwfbadminton.com/statutes/> (accessed on 26 March 2022)). The participation number of the Super 1000 and 750 is only 32 for each draw, and this includes the top 15 players, so it becomes difficult for other players who want to earn points, not to mention ranking 150 players. The numbers of participating players in all these competitions are limited; only the highest ranked player has the right of priority to engage in the competition till the total number of players participating has reached its maximum. Lastly, we choose career high ranking as an outcome measure for quantifying the player’s performance over winning percentage because the tournament’s earning points for each grade differ. Given this way of earning points, a player with a similar winning percentage could have a significantly varied career high ranking, which may undermine the current study’s reliability.

2.2. Equivalent Fraction: Trajectory Index

In this study, we introduce two pivotal parameters: T1, representing inherent talent, and A1, denoting the potential for future development in elite badminton players. It is crucial to understand that the essence of our analysis lies not in the numerical values of T1 and A1 but in their conceptual significance. T1 encapsulates the innate abilities and early indicators of a player’s prowess, while A1 forecasts their capacity for growth and advancement in their career. By focusing on these concepts, we aim to provide a deeper understanding of what drives success in professional badminton beyond mere statistical measurements. For the trajectory index (see Equation (1)), these two parameters are used to model the trajectories of career progression. Specifically, T1 was the time spent to make the top 150, whereas A1 was denoted as the age at which a player made it to the top 150. Players who achieve their highest world ranking at a younger age tend to have longer careers and achieve more tremendous success in winning major international tournaments compared to those who reach their peak later. Therefore, the age at which a player makes it to the top 150 in the BWF ranking can provide insight into their potential for long-term success in the sport. Likewise, players who make it to the top 150 in a shorter time tend to have more significant potential for future success than those who take longer. This is because players who reach the top 150 in a shorter time usually have a more exceptional talent or better access to training and coaching than those who take longer. Both T1 and A1 in the equation were applied to each player in this study. T1 could be assumed as a function of talent in the player, indicating less time spent making the top 150 and more time spent learning from those best master players. To mitigate possible confoundment by the sum of squares in A1, we applied a weighted average with a time constant accounting for the relative contribution of T1 to standardize equal contributions between A1 and T1. (For detail, see Equation (2)). Together, the trajectory index depends on the time of age and the time spent to make it to the top 150. The sum of two squares of the value will mostly rely on the more significant number. Since both key terms should contribute equivalently, this leads to a weight term. The higher trajectory index suggests more effort to rank up to the top 150, while the lower trajectory index indicated less effort to rank up to the top 150.

To further delineate the role of nurture in career progression, we introduced the nurture index, which is the time spent to make it to one's highest rank in the top 150.

In Equation (2), N is the number of players meeting our criteria while $T1_i$ and $A1_i$ are $T1$ and $A1$ for each player, respectively.

$$\text{trajectory index} = \sqrt{T1^2 + (\text{weight} \times A1)^2} \quad (1)$$

Equation (1). Trajectory index.

$$\text{weight} = \frac{\sum_i^N (T1_i)/N}{\sum_i^N (A1_i)/N} = \frac{\sum_i^N (T1_i)}{\sum_i^N (A1_i)} \quad (2)$$

Equation (2). Weight.

2.3. Statistical Analysis: Bayesian Regression Model

To examine the early specialization in sports and relative age effects, we conduct descriptive statistics to summarize the data of birth months and age data with frequency distribution differences across athletes. We then examine whether the career progression of elite men's and women's singles badminton players can be predicted by the age of debut on the world stage and the time spent to make the top 150. We first examine the linear relationship between the trajectory index and career high ranking across all players to test this. We then perform the predictive analytics with a linear regression model using Bayesian statistics [14]. Specifically, Bayes factor (BF) hypothesis testing will be used for Bayesian inference (Figure 3). Regression coefficients (e.g., R-squares, R^2) are also provided, examining how much variance the model explains using the predictors provided. R^2 is used to quantify how strong the effect is by adopting the coefficient of determination in correlation, showing how much of the variation in the career progression of elite men's and women's singles badminton players' variable can be predicted by two variables: the age of debut on the world stage and the time spent to make the top 150. The sum of squares (SS_M) is used to determine the fitting performance, measuring how close the actual data points are close to the modeled regression line. This indicates how much better the model is compared to just using the mean of the outcome variable. In this model, the F statistics are provided to assess the prediction of SS_m and residual error (the vertical difference between the data points and the predicted regression line are known as the residuals.). After adjusting for birth month, we compare the regression model with and without covariates. The regression plot with residuals and the Q-Q plot is provided (see Figure 4A–D). All statistical testing with Bayesian statistical [14] analysis is conducted using JASP (<https://jasp-stats.org/>) (accessed on 26 May 2022) [15]. All summary statistical measures for reporting results follow guidelines [15].

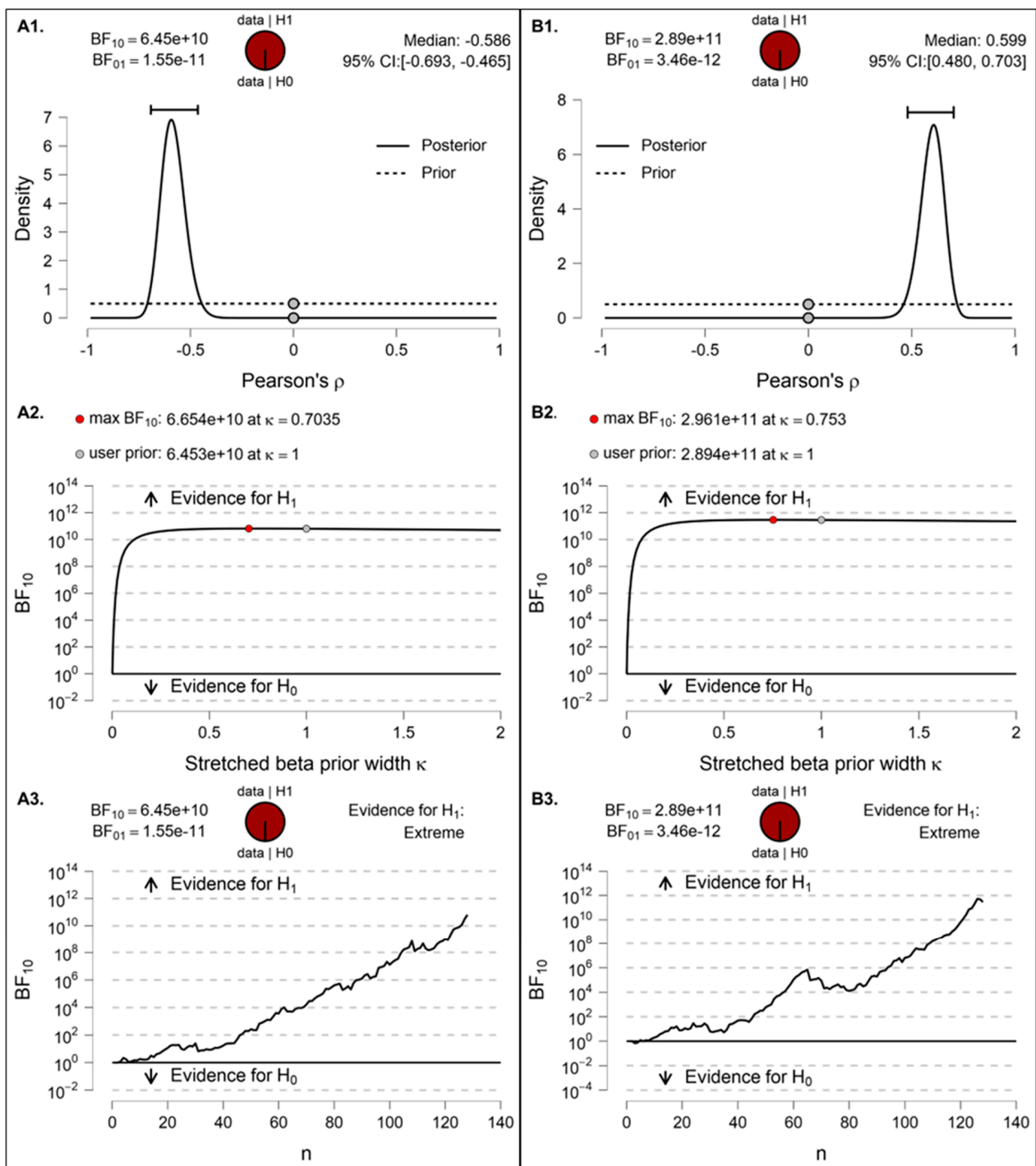


Figure 3. The Bayesian correlation pairwise plots. A = trajectory index, B = nurture index. (A1). Prior and posterior of Bayesian correlation model. (A2). Bayes factor (BF) robustness check. (A3). Sequential analysis. (B1). Prior and posterior of Bayesian correlation model. (B2). Bayes factor (BF) robustness check. (B3). Sequential analysis.

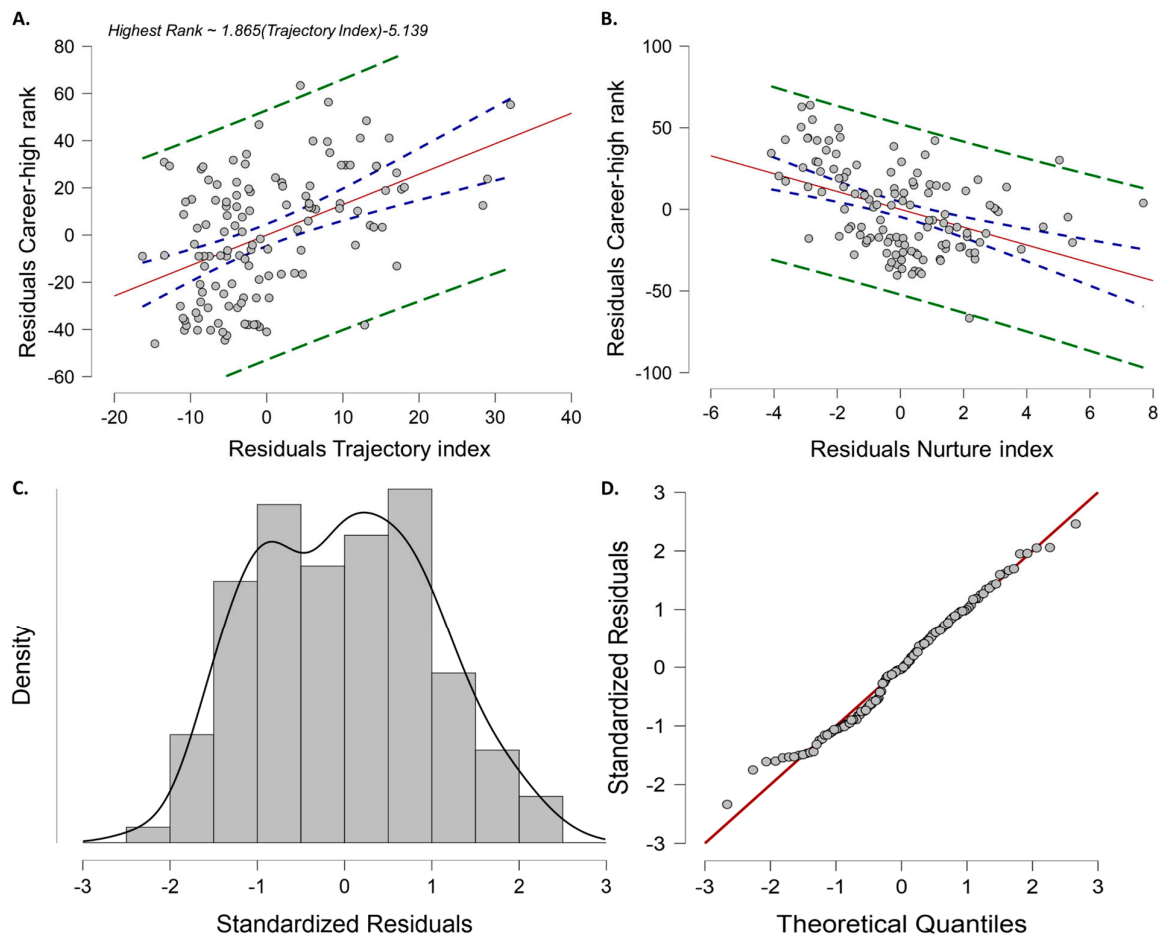


Figure 4. Partial regression residual plots. (A). Residual plot for trajectory index vs. career high ranks across all players. (B). Residual plot for nurture index vs. career high ranks across all players. (C). Standardized residuals histogram. (D). Q-Q plot. Blue dashed line = 95% confidence intervals. Green dashed line = 95% prediction intervals. Red line = line of best fit.

3. Results

3.1. Descriptive Statics

The frequency distribution across months in players is reported in Figure 2. Specifically, the average age of women's singles players to make the top 150 is 19.3 years (± 2.774), whereas the average age of men's singles players to make the top 150 is 20.5 years (± 2.673). Moreover, the average age of women's singles players to make it to the career high ranking is 23.2 years (± 3.008), whereas the average age of men's singles players to make it to the career high ranking is 24.3 years (± 2.849). The win percentage is 0.588 (± 0.111) in women's singles players and 0.616 (± 0.070) in men's singles players.

3.2. Correlation Analysis

Pearson's coefficient measures are reported in quantifying the strength of the linear relationship between key variables in this study. Of these variables, a significant correlation among variables was observed, especially in the positive relationship between the trajectory index and career high ranking across all players ($p = 2.813 \times 10^{-14}$, Pearson's $r = 0.608$, $BF_{10} = 2.894 \times 10^{11}$). Also, a significant negative correlation was observed between the nurture index and career high ranking across all players ($p = 1.318 \times 10^{-13}$, Pearson's $r = -0.595$, $BF_{10} = 6.453 \times 10^{10}$) (see Figure 3).

3.3. Regression Analysis

A Bayesian linear regression is used to predict the career high ranking of men's and women's singles badminton players from the trajectory and nurture indexes. Results (see Figure 4A–D) show that both indexes explain significant variances in career high ranking performances in men's and women's singles badminton players ($F(2,125) = 60.318$, $R^2 = 0.491$, $RMSE = 23.626$, $p = 4.610 \times 10^{-19}$). After observing data, the odds in favor of our constructed predictive model containing two indexes as a predictor increase by 189593.484. Bayesian inference for hypothesis testing of our predictive models, indicating strong evidence of rejecting the null hypothesis and favoring our model (see Table 1). Two predictors (i.e., the trajectory and nurture indexes) provide significant relative predictive adequacy of the given model compared to the best-fitting model. Specifically, the observed data are 58,173.3 times more likely under the model containing the trajectory and nurture indexes as predictors than the model containing only the trajectory index, whereas they are 255,819.90 times more likely under the model including the trajectory and nurture indexes as predictors than the model containing only the nurture index. Moreover, the QQ plot was reported in Figure 4D, suggesting that both assumptions of normality and linearity have also not been violated. Additional analysis observed a linear relationship between the age of a player who made it to the top 150 is associated with the age of a player who reached a career high ranking ($p = 2.839 \times 10^{-17}$, Pearson's $r = 0.659$, $BF_{10} = 2.386 \times 10^{14}$ (95%CI: 0.542~0.743)). Further regression analysis suggested the age variances of a player who reached a career high ranking can be explained by the age of a player who made it to the top 150 ($F(1,126) = 96.632$, $R^2 = 0.434$, $RMSE = 2.243$, $p = 2.839 \times 10^{-17}$).

Table 1. Overview of model comparison.

Models	P(M)	P(M Data)	BF _M	Log(BF ₁₀)	R ²
Trajectory Index + Nurture Index	0.333	1.000	189,593.484	0.000	0.491
Trajectory Index	0.167	8.594×10^{-6}	4.297×10^{-5}	−10.971	0.369
Nurture	0.167	1.954×10^{-6}	9.772×10^{-6}	−12.452	0.354
Null model	0.333	9.089×10^{-17}	1.818×10^{-16}	−36.937	0.000

4. Discussion

We examine if the age and time spent from debut to the top 150 on the professional badminton world stage could significantly impact later achievement. Results found that the career progression of elite singles badminton players can be predicted by the age of debut on the world stage and the time spent to make the top 150. Descriptive statics suggest that early specialization in sports may not be the case for elite badminton players, as none of the athletes made it to the top 150 before puberty. Specifically, most athletes were born from September to November or June to August. Our findings suggest that early career prospects could lead to prosperous careers in elite badminton players, explaining almost half of ranking variances in modern badminton. Regarding a player's career high ranking, talent comes first, whereas a higher rank needs more time to grow. Together, this notion could illustrate why the nurture index still explains considerable ranking variances. These findings highlight the importance of searching for talented athletes from a young age and helping them develop into elite athletes early to gain athletic success.

We explore if early-career success in badminton may beget an individual's future-career victories. Our results suggest a robust quantitative answer, that career high ranking performance can be predicted by the age at debut and time spent making it to the top 150 after adjusting for birth months across all players. These findings align with our hypothesis that promising performance delivered on the professional world stage at an early age significantly impacts later achievement. However, we know that accomplishment can be attributed to early specialization in sports at a relatively young age. If early specialization in sports could impact accomplishment later, we may observe the considerable proportion of athletes who made their top 150 debut before puberty. Specifically, we could observe

the differences between the number of athletes in different birth months. The average age for girls to start puberty is 11, while for boys, the average age is 12. We thus provided quantitative evidence on the association between the age and birth month distribution of these elite badminton players concerning their career high ranking. Our data suggested that badminton players reached the top 150 during middle to late adolescence, indicating that early-career success is still made through puberty. These results suggested the possibility of early specialization in sports associated with achievement. There are racial and ethnic differences in pubertal development, which could be worth investigating to see whether ethnic differences play a role in early-career success. In our study, most players who experience early-career success are Asian, indicating racial/ethnic advantages or social/cultural inequity in sport participation. Moreover, most early specialization athletes quit sports at a young age; this is not the case in this study, since most athletes are still competing.

Furthermore, our findings with additional information imply that naturally talented badminton players required less time and fewer resources to make the top 150 compared to less talented players. Nevertheless, our findings (see Figure 5) showed that with more time and resources invested, talented players would thus demand more time to grow to reach their career high ranking than those less talented players. Nonetheless, with abundant resources and time to nurture, the less talented players can still achieve the same level of accomplishment (i.e., make the top 150) at a relatively young age. However, the less talented badminton players also required more resources and time to nurture to progress further in the rankings, especially in the top 150. Although the observation suggests that talented and less talented players require resources and time to be nurtured, talented players have a longer athletic career than those less talented players. Often fame comes with responsibility; more resources nurture those talented players and let them rank higher than those less talented players. This phenomenon does not mean less talented players are unlikely to rank up after making the top 150; instead, it is still possible to make the top 5 if more resources and time are invested in nurturing those players longer than those with natural talent. Together, players who are talented have greater efficiency in leveraging resources and time to boost their ranking performance than those who are not.

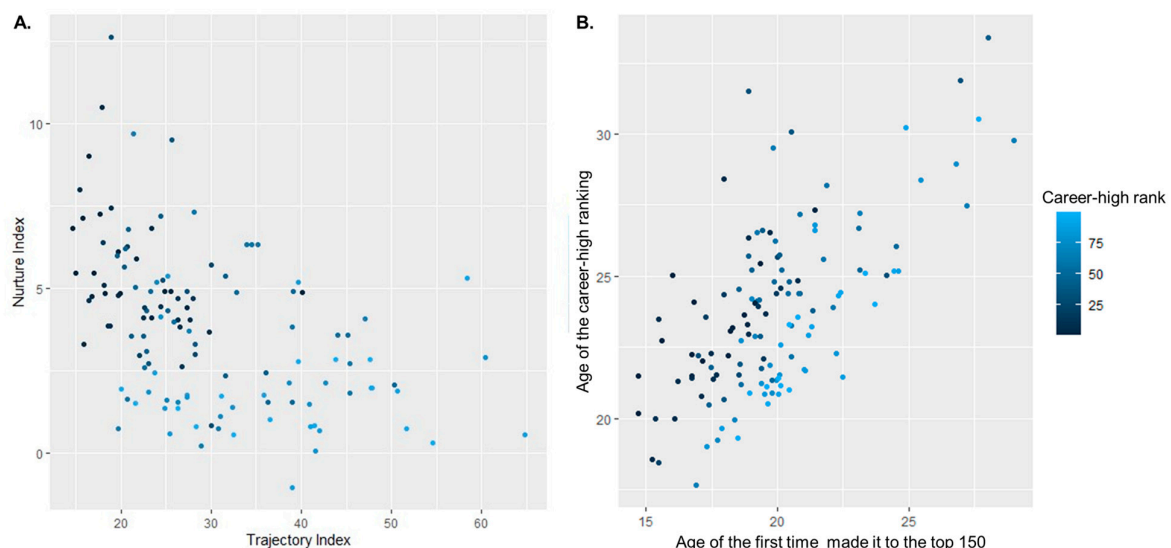


Figure 5. (A). Association between trajectory index and nurture index. (B). The A1 (i.e., the age at which a player made it to the top 150) and the age of the career high ranking. The darker blue indicates a higher ranking, whereas lighter blue indicates lower ranking performance in players.

Despite fruitful findings in this study, the Matthew effect [16] implies that accumulated advantages in those who begin with advantages accumulate more over time than those who begin with a disadvantage. These factors cannot be overlooked in our study, not only for their impact on the progressive decline of slow starters but also on the widening gap

between slow starters and fast starters. These points of view suggest that early career success leads to future success. The argument of the Matthew effect is explained mainly by diminishing resources. It is increasingly difficult for slow starters (or low-ranked individuals) to increase their resources, as they have fewer resources to risk over time, and it is increasingly easy for high-rank individuals to preserve a resource they already have, as they have a large amount to risk. That is, the more resources invested, the higher a player's rank is. However, this is not the case for badminton players with early career success, and we found that not only did those naturally talented badminton players spend less time making the top 150 from their debut than those less talented badminton players, but they also spent less time attaining a higher ranking. Also, our findings suggest that not only are nurture factors such as resources and time crucial, but the factor of nature in the player also outweighs these nurture differences. Likewise, the age of a player who made it to the top 150 is associated with the age of a player who reached their career high ranking, suggesting the importance of the nature of talented players who are younger when they made it to the top 150 requiring a longer time to cultivate to reach higher ranking in the later career success (higher rank). Hence, the less talented players may indicate a lower ceiling of ranking performance due to a shorter time to be cultivated and constrained by its potential. Therefore, we could minimize the Matthew effect based on quantitative evidence of nature and nurture periods in an early fastest starter of elite badminton players.

A few limitations need to be acknowledged despite the promise of studying career progression in badminton players using various statistics to model their early development and later success trajectories. The BWF's player ranking system only documents players as early as October 2009, which may undermine the internal validity of quantitative evidence in experimental design. Moreover, only a handful of players can meet the criteria to be included in our model; future studies should focus on those who nearly made it but did not get into the top 150 to understand the factors affecting failure and the ceiling effect in players' performance. Lastly, we choose career high ranking as an outcome measure for quantifying the player's performance over winning percentage because the tournament's earning points for each grade differ. Given this way of earning ranking points, a player with a similar winning percentage could have a significantly varied career high ranking, which may undermine the current study's reliability.

Practical Applications

The findings highlight the importance of identifying talented athletes from a young age and helping them develop into elite athletes early to gain athletic success. For athletes, the study suggests that achieving early success in their careers may lead to prosperous careers. However, it is essential to note that nature plays a significant role in an athlete's success trajectory. Therefore, it is crucial to continue nurturing their skills and investing resources and time to further their rankings. For coaches, the study emphasizes the importance of identifying and nurturing young athletes' skills to maximize their potential. The study also suggests that early specialization in sports may not be the case for elite badminton players, and it is crucial to allow young athletes to explore different sports and activities to discover their talents. Additionally, the study suggests it may be worth investigating racial and ethnic differences in pubertal development to ensure equal opportunities for young athletes. Future studies are encouraged to collect large-scale data by quantifying different expertise to see if the trends and patterns persist and could have implications for identifying and nurturing individuals with the potential to accomplish extraordinarily.

5. Conclusions

Our findings provide a robust quantitative answer that early career prospects could lead to prosperous career high rankings in elite badminton players, explaining significant ranking variances in the modern badminton world. Specifically, the observed performance differences can be used to determine potential early specialization and relative age effects. Also, we found that the Matthew effect may not explain early-career success in badminton

players at a young age, while nature outweighs nurture in future athletic career success trajectories. These findings highlight the importance of searching for talented athletes from a young age and helping them develop into elite athletes early to gain athletic success. Specifically, we document quantitative patterns governing the careers of the modern badminton world, offering an empirical basis for the computation parameter in predicting exceptional badminton careers in science.

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Data Availability Statement: The data that support the findings of this study are openly available in the Badminton World Federation’s official rankings archive at <https://bwfbadminton.com/rankings/>. This dataset was utilized for both analysis and generation of new insights as part of the study.

Conflicts of Interest: The authors declare no conflict of interest.

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