

## Article

# Uncovering Success Patterns in Track Cycling: Integrating Performance Data with Coaches and Athletes' Perspectives

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**Featured Application:** The findings of the present study may inform decision-making for track cycling coaches and practitioners in planning talent identification and development strategies. Moreover, the results presented raise concerns and underscore the importance of distinguishing between primary and secondary factors when aiming to support future talent in track cycling.

**Abstract:** Track cycling entails a challenging progression from the youth categories to elite competition. Hence, this study aimed to investigate the importance of early performance and various publicly available performance indicators in predicting the success of male and female cyclists across different track disciplines. Additionally, the study enriches the findings by incorporating interviews with international-level coaches and athletes. A retrospective analysis of data from UCI track cycling databases was conducted, supplemented by interviews with international-level coaches and athletes. The success rate for highly ranked junior track cyclists was found to be less than 20%, with a majority of these athletes specializing in sprint events, regardless of gender. The study indicated that the UCI ranking and points earned during the season were not reliable indicators for distinguishing future success ( $p < 0.05$ ). From the interviews, we identified three main themes: (1) trends in career success from the youth to elite categories, (2) performance markers as predictors of future success, and (3) the challenges and time involved in reaching elite categories. Junior category performance alone may not be the sole indicator of future success in track cycling. However, integrating performance analyses with practitioners and athletes' perspectives enables a deeper understanding of the results and the developmental context.

**Keywords:** scouting; talent identification; cycling performance; youth



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## 1. Introduction

Track cycling is a bicycle racing sport that showcases the skill and expertise of athletes as they masterfully navigate their fixed-gear bicycles around a banked track, propelling themselves to remarkable speeds in their relentless quest for the quickest race completion time [1].

Track cycling races encompass two main categories: sprint and endurance. These categorizations are based on the varying distances and demands placed upon the cyclists

during the races [1,2]. Sprint events, such as team sprints or keirin, are characterized by a shorter duration, sometimes lasting as little as 9 s. On the other hand, endurance events like scratch or points races extend beyond 3.5 min (i.e., team pursuit), usually spanning between 10 to 60 min in duration.

In the pursuit of achieving sporting excellence, the development of athletes typically begins in the youth categories. Track cycling, renowned for its demanding nature, presents a complex and intricate journey from the youth categories to elite-level competition [1]. In order to optimize this process, coaches, practitioners, and athletes actively seek evidence-based insights. These insights have the potential to aid in the identification of future talent, providing valuable guidance to propel them toward their training and performance objectives [2,3]. However, evidence regarding potential reliable performance indicators that are readily accessible to coaches and practitioners in the field is lacking. Furthermore, the role of success in youth categories as a predictor of senior elite success remains a subject of ongoing international debate in sports science, medicine, and physiology [4]. While the evidence suggests that successful youth athletes and successful senior elite athletes are distinct populations [4], there is a dearth of information within the context of track cycling.

In this context, the examination of potential markers that can forecast future success among youth category cyclists has emerged as a concept of great significance [4–6]. The importance of this lies in the far-reaching implications for coaches and practitioners in their final decision-making processes, the opportunities presented to athletes by national and international federations, and the athletes themselves as they navigate their career paths [4,6,7]. The consideration of reliable or unreliable indicators could profoundly impact these stakeholders and shape the trajectory of a cyclist's journey.

While the research focus has primarily centered on road and off-road cycling [8–11], the past two decades have witnessed numerous endeavors to explore and unveil the potential key factors influencing track cycling performance [2]. However, to date, little attention has been paid to characterizing the success rate of youth talent transitioning to the elite categories and elucidating the performance indicators that unveil their potential in the realm of track cycling [5]. Furthermore, the majority of the studies in this field rely on retrospective database analyses, effectively tracing career trajectories and identifying potential performance indicators [5,8,9], yet they often overlook significant additional aspects such as the interpersonal experiences among coaches in talent identification and selection and the athletes themselves [12].

In that regard, a landmark study conducted by Schumacher and colleagues meticulously tracked the evolution of performance across various track cycling disciplines, providing a comprehensive evaluation of its distinct features over a span of 20 years [5]. This extensive investigation encompassed both genders and included an analysis of the performance trends within both the elite and junior categories, offering valuable insights into the sport's development. While this study stands as a notable contribution [5], the majority of research on this topic has predominantly focused on road cycling. Within this context, the performance of youth cyclists, particularly starting from the junior category, has emerged as a promising indicator for predicting future success within the elite category of road cycling [8,9,11]. Furthermore, several hypotheses have been proposed regarding this topic, including the exploration of the potential influence of the relative age effect (RAE) or birthplace effect, which may confer advantages or disadvantages in achieving future success. Due to the classification based on birth year, athletes born at different extremes within the year may present significant variations in physical, physiological, and psychological development in youth categories [13]. In the realm of road cycling, which predominantly emphasizes endurance, the RAE appears to primarily impact early performance, with its effects diminishing as athletes progress beyond the junior category [9,14].

Furthermore, hypotheses have also been raised concerning the gender differences in the predictive power of youth performance, considering the divergent developmental paths of males and females [15,16]. However, to the authors' knowledge, studies investigating

this specific topic in the realm of cycling, particularly in track cycling, remain scarce or non-existent.

Therefore, the main objective of the present study was to explore the significance of early performance in predicting future success, as well as the role of various publicly available performance indicators in forecasting the performance of male and female track cyclists across different disciplines. Furthermore, the study aims to complement the quantitative analysis based on publicly available databases by incorporating the insights and perspectives of international-level coaches and athletes through open interviews, thereby enriching the findings.

## 2. Materials and Methods

### 2.1. Study Design

The present study consisted of two parts: (1) a retrospective quantitative analysis that examined data from publicly available Union Cycliste Internationale (UCI) databases (<https://www.uci.org/discipline/track/rankings>, accessed on 14 March 2022) and (2) a qualitative analysis that involved extracting data from interviews conducted with track cycling coaches and athletes. For the interviews, the participants were contacted either by text or verbally by using the snowball method (i.e., identifying and recruiting participants through referrals from existing participants who met the criteria) [17]. Prior to participating in the interviews, all individuals willingly provided written informed consent. The research protocol adhered to the Declaration of Helsinki and was approved by the Ethics Committee of the Lithuanian Sports University (MNL-SVA (M)-2023-597).

### 2.2. Quantitative Data Analysis

The quantitative data analysis involved extracting performance-related data, including the rankings and points scored from publicly accessible UCI databases. The data extracted included the season classification, nationality, birth date, and UCI points score. The age was calculated according to the UCI junior category regulations, taking the difference between the year of the classification and the rider's birth year. The data covered 4 different track cycling disciplines, 2 endurance (points race and scratch) and 2 sprints (sprint and keirin), for both male and female athletes in the junior and elite categories over ten years, with a two-year gap between the junior and elite databases (i.e., 2009–2018 and 2011–2020, respectively). The time frames were selected based on the year of availability of the databases, ensuring sufficient time for the cyclists to transition from the youth to senior categories, and considering the stability of the UCI point classification rules during the period. The athletes were ranked in their respective databases according to UCI regulations (<https://www.uci.org/inside-uci/constitutions-regulations/regulations>, accessed on 14 March 2022). The study focused on the top 10% of ranked junior cyclists and the top 20 male and top 10 female elite cyclists. A similar approach was previously described in a previous study [8]. A total of 2348 observations were collected, and 1564 cyclists were analyzed after eliminating the redundant names. Among these cyclists, there were 1008 men and 556 women. A cyclist's name was considered redundant if it appeared multiple times within the same category and discipline. To address this, certain variables were calculated from the original database to retain only one occurrence per name. These variables included the corrected score, age at maximal scoring, age at first appearance in the database, number of appearances in the junior category, time taken to reach the elite category, and month of birth. The corrected score was calculated based on the UCI score, aiming to mitigate the effects of potential changes in the scoring regulations and differences in points availability between the seasons. The formula used for this calculation was as follows:  $Corrected\ score = (Score_{Rider} - \overline{Score}_{Year}) / \sigma_{Score_{Year}}$ , where  $Score_{Rider}$  represents the score of the rider;  $\overline{Score}_{Year}$  denotes the mean score of the riders from the same year, sex, category, and discipline; and  $\sigma_{Score_{Year}}$  represents the standard deviation of the score within that same population. In the secondary database, the rankings and corrected scores were presented as the median/average, maximum, and minimum values for each rider.

This allowed us to summarize the performance while ensuring only one occurrence per name. The reference for the time to reach the first elite top classification was set as 1, being a successful transition achieved in the first season after leaving the junior category. The months of birth were divided into quartiles according to the methodology described by Voet et al. to account for the RAE [14]. Furthermore, riders were labeled as “achievers” if they reached, at least once, the top classification in both the junior and elite classifications within the same discipline. The “achiever” category pertains to the observations within that population during the junior years.

### 2.3. Qualitative Data Analysis

For the qualitative data analysis, the participants were recruited using the snowball method and by consulting the national and international databases linked to national teams and independent cycling teams following a protocol similar to that described in a recently published study [12,17]. A total of ten individuals; six coaches, and four athletes, comprising members from the national teams of France, Italy, and Lithuania known to the research team, participated in the study. Specifically, we recruited track cycling athletes or former athletes with at least 5 years of experience and at least one competitive season at the international UCI level, as well as coaches or former coaches with at least 5 years of experience and who had collaborated with national teams. The interview questions were designed to investigate the coaches’ and athletes’ experiences in track cycling at both the junior and elite levels in relation to the findings that emerged from the retrospective database analysis. The questions covered three main domains: (a) trends in career success from the youth to elite categories in track cycling; (b) performance markers as predictors of future success in track cycling; (c) time and difficulties associated with reaching the elite categories in track cycling (Supplementary Materials).

The potential interview questions were drafted and analyzed by each researcher. Three members of the research team (LC, TL, and TV), who have extensive involvement in the sport of cycling as athletes, coaches, and researchers, contributed to provide a deep understanding of the context of track cycling and to enhance the relevance of the interview questions. Additionally, the efficacy of the questions was evaluated during pilot simulations involving experienced members of the research team and a cluster of cyclists with whom they were collaborating, with the entire process and results being evaluated by a highly skilled coach [18]. Only the questions deemed appropriate, easy to understand, and generating responses specific to the aim of the present study were selected [19]. As a result, the interviews were semi-structured and conducted via online meeting platforms. The interviews were conducted individually online and lasted for approximately 30 min each. The first two questions aimed to collect background information on the participants’ cycling experience, while the remaining questions were directed towards the three previously described domains. After that, the participants were encouraged to provide natural recounts and anecdotes from their cycling experience without any interference from the interviewer. The interviews were conducted in the national language of the participant whenever possible (i.e., Italian, French, and Lithuanian). The recorded interviews were then converted into audio files, transcribed, and translated into English. The responses were grouped into questions, enabling a comparison of the interviews in terms of the similarities and differences. The results of the interviews were extracted, focusing on the three main domains (i.e., a, b, and c), summarizing the main outputs that emerged from all the interviews for each one.

### 2.4. Statistical Analyses

The statistical analysis was conducted using RStudio software (Posit Software<sup>®</sup>, Boston, MA, USA). Descriptive statistics were applied to the secondary datasets for both the elite and junior categories.

Considering the important number of variables being interrelated and conveying potentially similar information, a principal component analysis (PCA) was performed on

the junior dataset to define which ones should be retained for further analysis. Dimensions that accounted for a cumulative variance exceeding 90% were considered, and one variable that best aligned (positively or negatively) with each dimension was selected for further analysis.

Since the number of individuals in the achievers group was relatively small in each category ( $n < 25$ ) and the assumptions for the parametric tests were rarely met, the comparisons of the corrected scores between the non-achievers and achievers groups were performed using the one-tailed Mann-Whitney U test. The effect size ( $r$ ) was estimated by dividing the test statistic by the square root of the sample size. An  $r$  value was interpreted as a small effect between 0.10 and 0.29, a moderate effect between 0.30 and 0.49, and a large effect over 0.50 [20]. These tests were performed for each division of category, discipline, and sex. Logistic regressions were employed to assess the likelihood of becoming an “achiever” based on the age of the first Junior top ranking and, subsequently, the number of top rankings achieved during the junior years. To examine the RAE within the four birth month categories, a chi-squared test was applied separately for the junior and elite datasets. However, the small group sizes ( $n_{\text{group}} < 20$  and  $n_{\text{quartile}} < 5$ ) within the achiever groups precluded the application of the same test to them. The effect size was calculated following Cohen:  $w = \sqrt{(\chi^2 / \text{sample size})}$ .  $w$  was interpreted as a:  $\leq 0.09$  small, 0.10 to 0.29 medium, and  $> 0.30$  large effect [21]. If a significant RAE was observed, the residuals were calculated as:  $z = (\text{observed frequency} - \text{expected frequency}) / \sqrt{\text{expected frequency}}$  according to Sharpe [22]. Residuals under  $-2.00$  were interpreted as an underrepresentation, while values over 2.00 were interpreted as an overrepresentation of the associated population. Comparisons of the average corrected scores based on the RAE categories were conducted using Kruskal-Wallis tests. Similarly, the achievers test was not included in this procedure. In cases of statistical significance, a post-hoc Dunn test with a Bonferroni correction was performed to determine which groups had significantly different corrected scores. A significance level of  $p$ -value  $\leq 0.05$  was adopted.

### 3. Results

#### 3.1. Quantitative Data Analysis: UCI Databases

##### Transition Rate from Youth to Elite Categories

Less than 20% of the top-ranked junior riders achieved a top elite classification, as outlined in Table 1. When considering the same gender, there was a greater diversity of riders in the endurance disciplines compared to the sprint disciplines in the junior category (women:  $n_{\text{sprint}} = 149$  and  $n_{\text{endurance}} = 226$ ; men:  $n_{\text{sprint}} = 299$  and  $n_{\text{endurance}} = 321$ ) and in the elite category (women:  $n_{\text{sprint}} = 80$  and  $n_{\text{endurance}} = 101$ ; men:  $n_{\text{sprint}} = 163$  and  $n_{\text{endurance}} = 227$ ). It is noteworthy that both in relative and absolute terms, the sprinters demonstrated the highest successful transition rate to the elite category, with only slight differences observed between the genders. In women’s cycling, the difference amounted to solely one rider ( $\Delta_{\text{absolute}} = 1$ ;  $\Delta_{\text{relative}} = 1.10\%$ ), while in men’s cycling, the difference was four riders ( $\Delta_{\text{absolute}} = 4$ ;  $\Delta_{\text{relative}} = 2.09\%$ ). The endurance disciplines showed wider populations of riders who did not achieve any top classification in the junior category compared to the sprint disciplines, regardless of gender ( $\Delta_{\text{women}} = 19$ ;  $\Delta_{\text{men}} = 56$ ). Moreover, male populations of those same riders were proportionally larger than women in each discipline ( $\Delta_{\text{sprint}} = 2.1\%$ ;  $\Delta_{\text{keirin}} = 6.5\%$ ;  $\Delta_{\text{scratch}} = 8.5\%$ ;  $\Delta_{\text{race points}} = 6.1\%$ ).

**Table 1.** Details of the population by discipline and sex and rate of conversion from the junior to elite categories.

Sex	Discipline	Total Juniors	Non-Achievers		Achievers		Total Elites
			n	%	n	%	
F	Sprint	75	61	81.33	14	18.67	38 (9)
	Keirin	74	61	82.43	13	17.57	42 (12)
	Scratch	108	97	89.81	11	10.19	55 (24)
	Points Race	118	109	92.37	9	7.63	46 (16)
M	Sprint	168	144	85.71	24	14.29	89 (23)
	Keirin	131	117	89.31	14	10.69	74 (26)
	Scratch	157	146	92.99	11	7.01	117 (61)
	Points Race	164	144	87.8	20	12.2	110 (45)

Notes: Part of the population expressed as percentages refers to the junior dataset. Total Elites: riders who reached the top classification in the elite category with no prior top ranking in the junior category.

The average median time for female cyclists to achieve their first top classification in the elite category following their departure from the junior category was  $3 \pm 0$  years, respective of their discipline. For male cyclists, the average median time for this transition was  $3 \pm 1$  years. Notably, the scratch discipline exhibited the longest median time, reaching 4 years (Table 2).

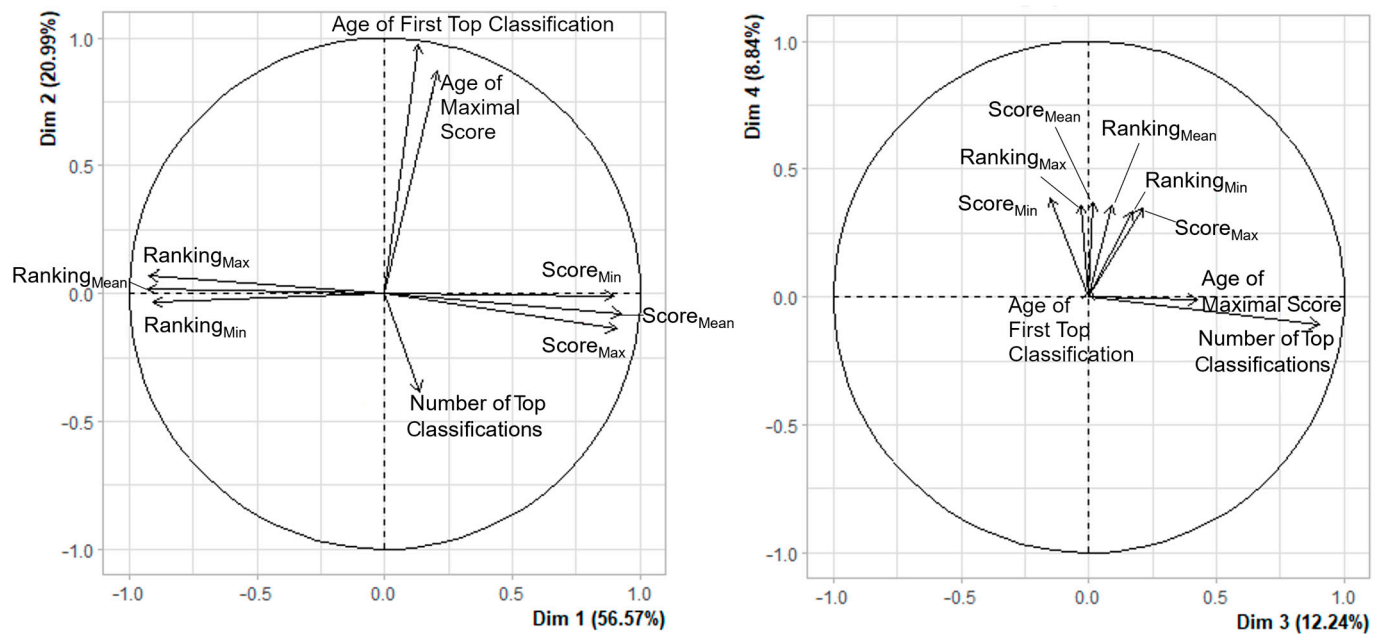
**Table 2.** Time (in years) to reach the top elite classification from the junior categories.

Sex	Discipline	1st Quartile	Median	3rd Quartile
F	Sprint	2	3	3
	Keirin	2	3	4
	Scratch	2	3	5
	Points Race	2	3	3
M	Sprint	1	2	4
	Keirin	2	3	3
	Scratch	2	4	4
	Points Race	1	2	3

Notes: A one-year time gap means the rider reached the top classification in the first elite season.

### 3.2. PCA

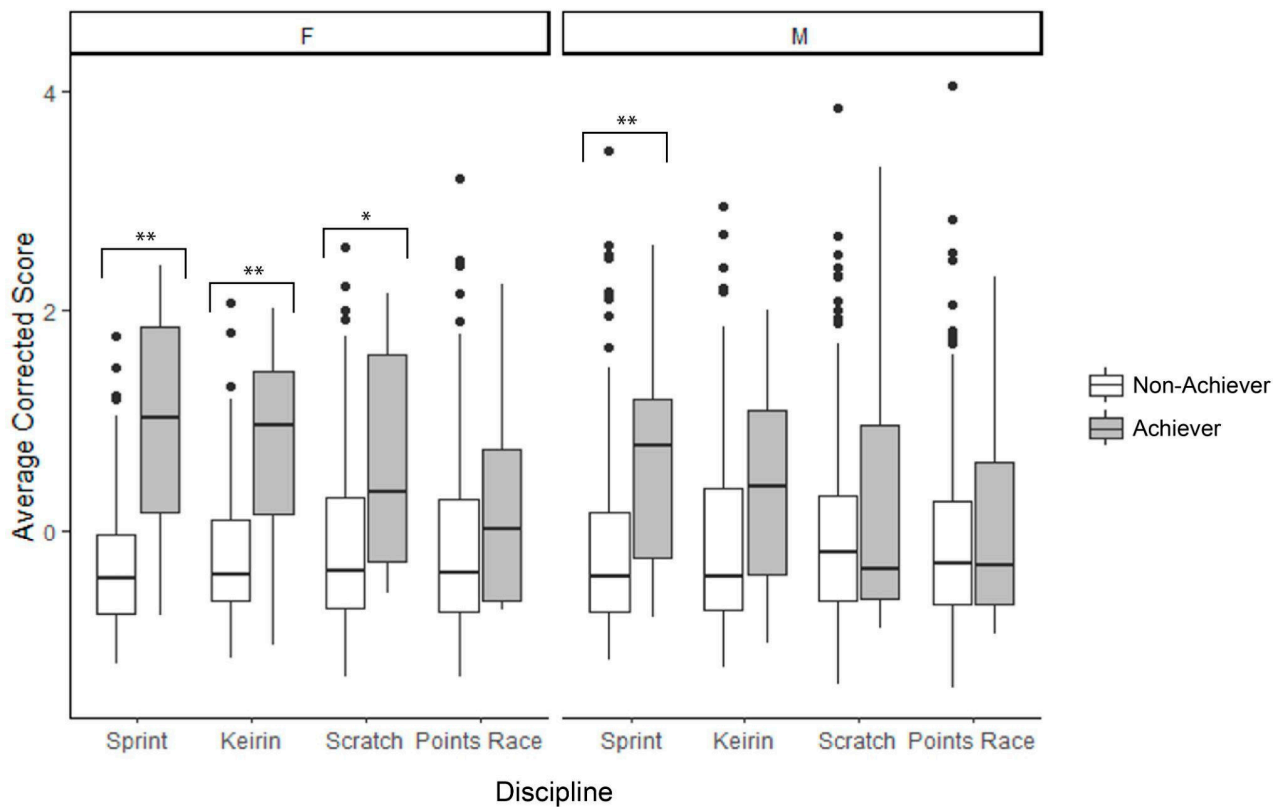
Four dimensions accounted for a cumulative variance of 98.64%. Considering the results of the principal component analysis (PCA) shown in Figure 1 and Supplementary File S1, it is justifiable to focus solely on the findings related to the average corrected score. This variable closely correlates with the ranking, the age of the first appearance in a top classification, and the number of appearances in the top classifications. Given that other variables may convey similar information, they were omitted from the presentation.



**Figure 1.** Association of the variables with the dimensions of the principal component analysis. Notes: Dim: dimension, Min: minimum, Max: maximum.

### 3.3. Performance Indicators

Women achievers scored higher than their counterparts in sprints with a moderate effect size ( $W = 137$ ;  $p < 0.001$ ;  $r = 0.45$ ), keirin with a moderate effect size ( $W = 140$ ;  $p < 0.001$ ;  $r = 0.42$ ), and scratch with a small effect size ( $W = 300$ ;  $p < 0.01$ ;  $r = 0.23$ ) (Figure 2). No significant difference was observed in the points race between the achievers and non-achievers in women ( $W = 367$ ;  $p = 0.11$ ,  $r = 0.12$ ). Considering men's disciplines, a significant difference regarding the corrected score between the achievers and non-achievers was found in the sprint discipline, with a small effect size ( $W = 922$ ;  $p < 0.001$ ;  $r = 0.28$ ). In other disciplines, no significant difference was observed either in keirin ( $W = 625$ ;  $p = 0.07$ ,  $r = 0.13$ ), scratch ( $W = 753$ ;  $p = 0.37$ ,  $r = 0.03$ ), or the points race ( $W = 1395$ ;  $p = 0.41$ ,  $r = 0.02$ ).



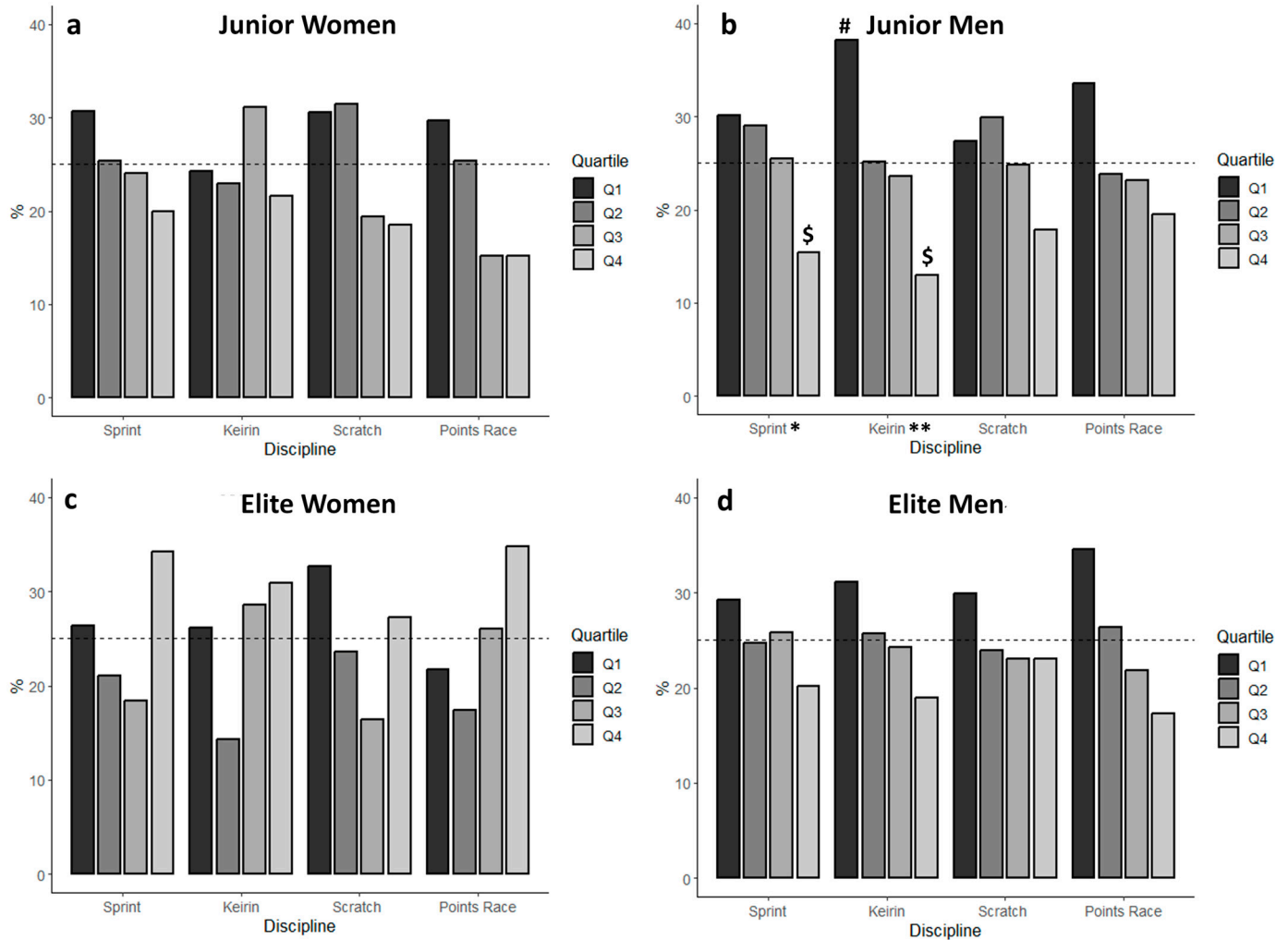
**Figure 2.** Average corrected score of achievers and non-achievers depending on the sex and the discipline. Notes: F: female; M: male; \*:  $p < 0.05$ ; \*\*:  $p < 0.001$ .

The age of the first top classification in the juniors and the number of top rankings achieved in the junior category showed no statistically significant relationship, except in the men's sprint group, for which the likelihood of being an achiever rose when reaching a first ranking on the last junior year ( $z = 2.84$ , OR = 4.29, 95% CI [1.6, 13.4]) (see Supplementary Materials). The number of riders reaching their first top classification in their first year ( $n = 83$ ) was close to the one for those reaching it in their last year ( $n = 85$ ).

### 3.4. Impact of the RAE

No RAE was found in the women's junior disciplines, neither in sprint ( $\chi^2 = 1.75$ ,  $p = 0.63$ ;  $w = 0.19$ ), in keirin ( $\chi^2 = 1.57$ ,  $p = 0.67$ ;  $w = 0.15$ ), in scratch ( $\chi^2 = 6.30$ ,  $p = 0.10$ ;  $w = 0.21$ ) or in the points race ( $\chi^2 = 6.54$ ,  $p = 0.09$ ;  $w = 0.24$ ) (see Figure 3a). In junior men, the RAE was effective in the sprint disciplines, i.e., in sprints with a medium effect size ( $\chi^2 = 8.14$ ;  $p = 0.04$ ;  $w = 0.22$ ), with an underrepresentation of Q4-born riders ( $z = -2.31$ ) and in keirin with a large effect size ( $\chi^2 = 16.8$ ;  $p < 0.001$ ;  $w = 0.36$ ), with an overrepresentation of riders born in Q1 ( $z = 3.01$ ) and an underrepresentation of riders with a birthdate from Q4 ( $z = -2.75$ ) (see Figure 3b). No RAE was found for men's endurance disciplines, namely scratch ( $\chi^2 = 5.11$ ,  $p = 0.16$ ;  $w = 0.18$ ) and the points race ( $\chi^2 = 7.07$ ,  $p = 0.07$ ;  $w = 0.20$ ).





**Figure 3.** Birthdate distribution of the riders in the junior women (a) and men categories and the (b) elite women (c) and men (d) categories. Notes: Q1: born between January and March; Q2: born between April and June; Q3: born between July and September; Q4: born between October and December; \*:  $p$ -value < 0.05; \*\*:  $p$ -value < 0.001; # post-hoc analysis indicates an overrepresentation; \$: post-hoc analysis indicates an underrepresentation.

No RAE was found in the elites in women's disciplines (Figure 3c) or men's disciplines ( $p > 0.05$ ) (Figure 3d). No significant influence of the RAE on the average corrected score was observed in any of the studied groups ( $p > 0.05$ ) (Supplementary File S2).

#### Qualitative Data Analysis: Interviews

Ten individuals from the national teams of France, Italy, and Lithuania participated in the interviews, including six coaches, all of whom had previous experience as athletes; three were active athletes, and one was a former athlete (see Table 3). Four of the six coaches had prior experience as international athletes.

**Table 3.** Description of the interviews' participants.

Occupation	Country	Sex	Years of Experience	Discipline	Active
Coaches (n = 6)	Lithuania	M	C:37	Endurance	Y
	Lithuania	F	C:4; A:14	Endurance	Y
	Lithuania	F	C:22; A:5	Sprint	Y
	Italy	M	C:12; A:16	Sprint	Y
	France	M	A:20	Endurance	Y
	France	F	A:12	Sprint	N
Athletes (n = 4)	Italy	M	A:20	Sprint	N
	Italy	F	A:12	Sprint	Y
	France	M	A:7	Endurance	N
	France	M	A:14	Endurance	N

Notes: M, male; F, female; C, coach; A, athlete; Y, yes; N, not.

### 3.5. Trends in Career Success from the Youth to Elite Categories in Track Cycling

The results from the interviews with the coaches and current and former athletes indicate that early success in the youth categories is not necessarily a determinant of future success in track cycling. While early success in sprinting may be a positive sign and more indicative than the endurance disciplines, developing the exceptional characteristics required for modern track cycling requires comprehensive athlete development through a multidisciplinary approach and training specificities.

*“Performing well in youth categories may be a possible indicator of future success, but it is certainly not the only one. . . early success may even be detrimental, in some cases, to an athlete’s future career. . .”*

*“. . .If an athlete is good at sprinting, it is often possible to see their potential for achieving high peaks in their future career in the same discipline at an early stage. However, this does not necessarily mean that they need to be developed specifically for sprinting to show exceptional early results. Sprinting is a capacity that not all possess, and developing a talented sprinter is like polishing a diamond. It’s important to ensure that their development is not suppressed by applying too much training volume and one-sided loads. . .”*

All interviewed coaches substantially agreed that the performance levels in the junior categories are getting closer to the elite level, with peak performance being reached earlier. Early performance in females may also be more representative of success due to their earlier biological maturity and the smaller number of athletes competing at high levels. According to the interviewees, the optimal age to start cycling is flexible, but rigorous and specific training should begin at approximately 17–18 years old.

A sustainable and heterogeneous approach to training and competitions emerged as the best choice, with the prioritization of athlete development rather than the results achieved in the youth categories. Support from coaches, teams, and parents, as well as mental fortitude and individualized training programs, are also crucial factors for career success.

However, at least two of the interviewed current and former athletes reported that being a top performer in the junior categories may represent a positive factor for future success at the international level by raising motivation and obtaining support from sponsors or national and private teams. They emphasized that without the results, there is less support, and with less support, the multidisciplinary approach and assistance from expert technicians could remain a utopian concept.

From the interviews, an additional potential aspect explaining the higher transition rate observed in sprinters compared to endurance athletes is the fact that, unlike endurance disciplines, where many athletes shift from road to track and vice versa easily, this is harder for track sprinters. Sprint disciplines in track require not only very specific physiological,

morphological, and psychological characteristics but also bike handling skills and proper technique. This may result in youth category sprinters representing almost the only pool from which future talent can emerge.

In summary, the athletes concur with the key points highlighted by the coaches in the interviews. However, they also emphasize the significance of attaining results to bolster self-confidence and motivation and garner support, such as sponsorships or team selection. Additionally, they acknowledge the challenges associated with solely relying on track cycling for livelihood.

### 3.6. Performance Markers as Predictors of Future Success in Track Cycling

Based on the interviews with the coaches and athletes, it appears that UCI scoring and ranking may not be reliable predictors of future success for junior track cyclists. While scoring points in the first UCI competitions was once important for impressing national team coaches and securing a spot in the team, the availability of more competitions now allows national teams to provide chances to more athletes and prioritize the strongest ones for the most important events. Therefore, single-race results and times are more significant for future selections than global points, especially at international competitions.

*“...in my experience as an athlete, the results of the first UCI competitions were crucial to impress the national team coach and secure a spot in the team for future events. Scoring points, especially in the early part of the season, was highly important. However, from a coach’s perspective today, there are now many more competitions, allowing national teams to give opportunities to a larger pool of athletes. The strongest athletes are reserved for the most important events, while secondary athletes are given chances to prove their worth in other competitions. As a result, the focus has shifted from accumulating global points to performing well in individual races and achieving competitive times at the international level. These results determine an athlete’s value for future selections. Furthermore, competing excessively can be expensive and detrimental if an athlete’s condition is not optimal. Therefore, it is now easier to make rounded selections and give more athletes the chance to compete while focusing on the most important events...”*

Furthermore, the analysis of the laboratory and field tests, coupled with the examination of the training data, can offer coaches more comprehensive insights. These insights are valuable for monitoring and guiding athletes’ progress, as well as aiding talent identification and selection processes. It is crucial to avoid placing too much emphasis on UCI scores and rankings too early on. Instead, a gradual approach to training and progression of training loads is key to a successful transition to elite track cycling from the junior level.

While UCI points are important for elite track cycling and qualifying for the world championships, coaches are less likely to consider UCI points for junior selections. Instead, junior world championships, junior European championships, and junior national championships are considered more important indicators of future individual success.

### 3.7. Time and Difficulties Associated with Reaching the Elite Categories in Track Cycling

Sprinters may reach the elite categories earlier, but they may also drop out faster if they fail to achieve results, considering the absence of a safety net like road cycling, which is available to endurance athletes.

*“...Track cycling sprint disciplines stand out as distinct entities within the sport, diverging significantly from endurance events where athletes often transition between disciplines. The unique performance demands and characteristics of sprinting necessitate a specialized approach to training, coaching, and nutrition for example. As a result, sprinters may devote their focus entirely to their discipline, potentially sidelining ambitions in other competitions. This singular focus presents challenges, requiring athletes to seek sufficient support to sustain their careers. These complexities can pose significant challenges for the longevity and even the initiation of sprinters’ careers...”*

However, according to one coach, this may be due to selection constraints, especially in important competitions such as the world or European championships, where only one endurance athlete can be selected, while sprint national teams can have up to three athletes. Coaches suggest that the optimal time to reach elite categories is approximately 3–4 years after the junior categories, at 21–22 years of age, with a successful transition being considered once an athlete ranks within the top 15. After this point, slower progress or at least maintenance of the same attained level is important until an athlete is likely no longer capable of progressing further, which is typically around 26 years old. Although the RAE may impact the sprint categories more than endurance, it is not considered a major factor in future success. Instead, the gradual and comprehensive development of skills is crucial, as emerged from the previous themes.

#### 4. Discussion

The present study sheds light on the limited predictive power of junior performance for future success in track cycling. The study also reveals a weak correlation between junior performance markers available from UCI databases and future success, regardless of gender or discipline. Moreover, the integration of the quantitative data analysis with the insights obtained from the interviews conducted with the field experts confirms the findings while also adding significant value and depth to the results.

##### 4.1. Junior Performance and Future Success

The study delves into the intricacies of junior performance in track cycling and its connection with future success. It emerged that attaining high-performance levels in the junior categories of track cycling does not necessarily guarantee future success in the elite categories, especially in endurance disciplines. Our findings indicate that high-performing junior track cyclists, regardless of gender, do not seem to have significantly greater chances of succeeding at the elite level. This trend is even more pronounced in the endurance disciplines, where the "non-successful" juniors demonstrated even higher probabilities of transitioning and succeeding in the elite categories. While direct evidence in track cycling is scarce, our data align with reports from road cycling studies, indicating a low predictive power of youth performance, which, however, tends to increase with age, starting from the early youth categories to the junior and U-23 categories [5,8,9]. A recent review by Gullich and colleagues further supports this notion by highlighting the low predictive power of junior performance levels across different sports in revealing future success [4]. Several factors could contribute to this phenomenon. First, biological development significantly influences success in the youth categories, and the relatively low percentage of athletes achieving later success in the elite category can be partly attributed to various biological factors associated with different maturation timings [23]. Moreover, differences in biological development may explain the lower success rates observed in endurance disciplines compared to sprint ones. Notably, for sprinters, excelling in the junior categories demonstrated a stronger predictive value for elite success compared to the endurance disciplines, regardless of gender. The characteristics of a sprinter are often detectable early in an athlete's career, while endurance performance requires more time and maturation to reach the highest levels [24,25]. This discrepancy is consistent with the observations of coaches, who highlighted in the interviews that sprint competitions tend to unveil more future champions at the youth level than endurance events, where the peak performance is typically achieved later [26]. Additionally, training load, race preparation, and the pressure to perform at high levels may serve as additional explanatory factors, but they can lead to achieving early high-performance levels at the expense of potential early burnout [4]. Changes in race formats and covered distances could also play a key role in explaining our results, particularly in endurance disciplines where athletes often combine track and road cycling activities. In our dataset, the average age was  $18.5 \pm 0.5$  years old for both male and female junior riders,  $26.1 \pm 4.2$  years old for females, and  $26.1 \pm 4.3$  years old for males in the elite category, regardless of the discipline. As athletes progress in their

training and competitions, their opponents' levels and the demands on their performance gradually increase, as confirmed by our interviews. However, this competitive pressure could be a double-edged sword since while many talents can emerge, there is also a risk that the process of selection and development of athletes is not optimal.

Our findings, along with existing literature, support the idea of prioritizing youth athletes' potential development overachieving high performances and competition results to ensure long-term performance progression throughout adulthood. Coaches emphasized the importance of a comprehensive approach to training and competitions in the youth categories to foster well-rounded development and create strong foundations for future success. Gullich and colleagues argued that the emphasis placed on youth category results and talent selection policies based solely on those results may be misguided [4]. As emerged from our interviews, athletes may experience pressure based on early results that could impact national team selection, international competition participation, and potential sponsorship opportunities for their future. An early focus on results may lead to the early dropout of future talent who have not yet fully expressed their potential.

Overall, our findings suggest that relying solely on junior performance as a predictor of future success in track cycling, particularly in endurance events, may not be sufficient to identify athletes with the greatest potential for long-term success. Instead, a more comprehensive approach that considers individual development and potential may better serve in guiding the pathway to elite success. Regrettably, there is a paucity of studies that specifically explore this topic in the context of track cycling. Consequently, a constructive comparison of our results with previous or additional studies is not possible at this time.

#### *4.2. Performance Indicators to Predict Future Success*

The identification of reliable performance markers plays a crucial role in physiology research and applied studies, aiding in training planning and talent selection [6,7]. While many studies have focused on describing the physiological profiles and training responses of youth and elite cyclists of different disciplines [3,10,27–29], track cycling remains an area with relatively limited investigation [2]. Moreover, exploring easily accessible performance data, such as those available in UCI databases, can provide valuable indicators of track cyclists' performance levels across different seasons [6].

In light of this, the present study identified a potentially more reliable indicator of future success, defined as the "corrected UCI points score". Achievers in track cycling tended to exhibit higher scores in the junior category compared to the riders who did not reiterate their high youth performances, which was notable in the sprint disciplines. Additionally, gender differences were observed, with a more pronounced scoring gap between the achievers and non-achievers in the female cyclists compared to males. However, it is essential to interpret these findings with caution, as the effect size of these differences was found to be relatively small. Therefore, even though the "corrected UCI points score" showed promise as a potential performance marker, it should be used judiciously as an indicative tool for future talent assessment. Recent studies have explored the value of publicly available data as a means to predict road cycling performance and identify talent among U-23 category riders [6]. However, uncertainties persist when considering younger athletes in the junior category. Various studies have suggested a trend toward weaker predictive power in the very early categories, but stronger predictability as athletes approach the U-19 and U-23 categories [8,9,11]. In the context of talent identification in track cycling junior categories, expert coaches, athletes, and former athletes acknowledge the limitations of relying solely on publicly available UCI indicators, especially considering the increased opportunities for showcasing throughout the season offered by a denser competition calendar. While achieving high UCI scores remains essential for qualification to events like the world championships, specific results obtained in key competitions emerge as richer/more meaningful indicators for talent scouts and national team selectors, attracting sponsors to support the future careers of young athletes at the same time. Moreover, advancements

in laboratory and field-based performance analyses could provide a more comprehensive understanding of an athlete's current physiological status and potential.

Overall, the present study sheds light on the potential value of the "corrected UCI points score" as a performance marker in track cycling. It highlights the significance of incorporating easily accessible UCI data alongside physiological testing as part of a more comprehensive performance analysis approach for talent identification and training planning. The UCI scores and derived indicators could serve as complementary markers, helping establish performance targets to qualify for prestigious events or quantifying the necessary competition experience to reach higher-level competitions. Nevertheless, coaches and athletes stress the need for further research and a cautious interpretation of the results to ensure the responsible use of such performance indicators in talent selection processes.

#### *4.3. Additional Factors Affecting Success*

To explore additional factors influencing future success or lack thereof, starting from the youth categories, the study considered the RAE and delved into career trajectories. In agreement with previous road cycling studies [9,11], no significant RAE was observed in the elite, irrespective of gender and discipline. This aligns with the prevailing pattern of the RAE being more pronounced before puberty and uncertainty surrounding its persistence into adulthood [30,31]. Notably, recent research in road cycling indicated that the RAE might manifest until the U-15 categories, gradually diminishing as athletes reach the U-19 category [9]. Indeed, the end of puberty in males is likely to occur during the junior years (i.e., between 16 and 18 years old), implying discrepancies in anaerobic capabilities, while most female athletes might have already reached the term of that maturation period [32]. Considering long-term performance development, becoming physically and mentally stronger at a later age may hold greater importance, especially in the endurance disciplines [26]. This notion was confirmed by interviews with coaches and athletes, where the consensus was that biological maturation might affect sprint disciplines more than endurance events but is not necessarily a major determinant of future success. Coaches' opinions also aligned with the study's results regarding the optimal time to reach elite categories. On average, a 3-year interval was observed, with coaches suggesting 3 to 4 years as the optimal time frame. Additionally, there was a trend toward shorter timeframes for achieving elite status in female athletes compared to males and in sprint disciplines compared to endurance events. Coaches highlighted the faster progression of female sprinters into the elite level, possibly explained by psycho-physiological factors related to performance maturation requirements in endurance capacity and the benefits of a more gradual development [26]. Practical considerations also played a role, as endurance track cyclists often have the option to compete in road cycling, while sprinters may focus solely on track competitions, potentially contributing to their earlier ascent to the elite level.

Overall, the combination of the database analysis and qualitative insights from the field experts shed light on phenomena like the RAE and provided a better understanding of ideal career paths in relation to gender and discipline. These findings contribute valuable insights into talent development trajectories and the factors influencing future success in track cycling.

The present study successfully highlighted the challenges in predicting future success solely based on competition results and publicly available performance indicators. By integrating these quantitative findings with the qualitative insights gathered from the interviews with field experts, the study revealed deeper and more nuanced perspectives. This emphasizes the importance of using publicly available database data as complementary sources to more comprehensive laboratory or in-field tests. The study underlines the importance of adopting a gradual and holistic development approach in the junior categories. It advocates for providing young riders with opportunities to engage in high-level challenges to gain valuable experience while placing less emphasis on short-term outcomes. Some of those challenges could be the integration of the young riders in training camps or the participation in international events, as mentioned by the interviewees. Further-

more, the study spotlights the heterogeneity of track cycling as a sport, suggesting that the performance levels of sprinters should be considered separately from those of endurance athletes. This differentiation becomes even more crucial when accounting for gender differences, where female athletes may exhibit earlier biological maturation. As a result, specific training and performance optimization strategies tailored to individual needs become important considerations [2]. Moreover, it is essential for current selection strategies in youth talent promotion programs to move beyond solely relying on scores or competition results to identify the highest-performing youth athletes. Coaches' opinions and insights should be offered due consideration to provide equal opportunities to all athletes who have the potential to excel in the future. By incorporating the expertise and judgment of experienced coaches, talent identification processes can become more well-rounded and inclusive, ensuring that promising young athletes are not overlooked based solely on current performance metrics. This approach fosters a more comprehensive and fair evaluation of athletes' potential, enabling the discovery of hidden talent and nurturing the development of future stars in the sport. Taken together, the present study highlights the complexity of predicting future success in track cycling. By incorporating both quantitative and qualitative data, a more comprehensive understanding of talent development and performance factors emerges. Emphasizing a gradual and complete athlete development approach, as well as accounting for the diverse nature of the sport and gender-specific considerations, can better support junior track cyclists on their path to success.

#### 4.4. Limitations

The study possesses several notable strengths, including its focus on an understudied sport, track cycling, and its involvement of a large international sample, encompassing various disciplines and both genders. Moreover, the study's innovative approach combining quantitative retrospective data analysis with qualitative data collection through interviews with field experts adds depth to the research questions posed. However, it is crucial to acknowledge certain limitations. Firstly, the study's descriptive nature restricts its ability to account for causal processes that may contribute to athletes' success or dropouts. As a result, it is challenging to establish direct cause-and-effect relationships. Additionally, limiting the analysis to a specific time interval (e.g., 10 years) offers methodological advantages, but it may also lead to potential oversight of late success achievers or those whose accomplishments extended beyond the designated time frame. In addition, the separation of data from the junior and elite categories by two years might underestimate some achievers who achieved success later, and the inclusion of riders who left the junior category earlier may also affect the estimation of achievers. Despite these limitations, the study still highlights that achievers remain a minority in both categories. Furthermore, the variability in the competitive levels across different years introduces complexity in interpreting the significance of athletes' scores or rankings. The shifting competitive landscape may impact the weight attributed to an athlete's performance metrics in different periods, affecting the overall evaluation. Lastly, while involving high-level practitioners in the field provides valuable insights, it also presents challenges in recruitment and may limit the number of potential participants in the interviews, potentially constraining the overall depth and breadth of qualitative data collected. In summary, the study's strengths lie in its focus on an unexplored sport and the use of a diverse and large international sample. The combination of quantitative and qualitative methodologies enriches the investigation. However, limitations in the study's design, such as its descriptive nature, temporal constraints, and variability in competitive levels, should be considered when interpreting the results. Despite these limitations, the study contributes valuable insights to the understanding of talent development and success factors in track cycling.

#### 4.5. Future Perspectives

Future studies could reinforce the current findings by enhancing the approach with the inclusion of performance indicators derived from laboratory or in-field tests, tracking

changes over time and across categories, and evaluating their predictive power for future success in comparison with main competition results, scores, and rankings. The present investigation highlights the benefits of integrating qualitative variables, such as in-field expert opinions, with quantitative variables. Replicating the current approach in different contexts could be considered in future studies. Additionally, exploring more qualitative variables, such as the country distribution, concentration of velodromes, and training infrastructures, and a more in-depth analysis of talent selection and support systems used by national and international federations, may shed further light on the factors influencing success in track cycling.

## 5. Conclusions

The present study has made significant contributions to characterizing several determinants of future success in an understudied population, such as track cyclists. By adopting an integrated approach that combines quantitative analysis of competition-derived markers with qualitative data obtained from in-field expert interviews, this study sheds light on the strengths and weaknesses of using publicly available institutional data as predictive indicators for future performances. It is evident from our findings that excelling in junior categories does not guarantee future success at the elite level. Rather, a more comprehensive approach to training, competition selection, and mental focus appears to be a more effective strategy for long-term performance development. Additionally, considering gender and discipline-specific factors can be crucial when designing training strategies and analyzing the performance of track cyclists to identify future talent. Overall, our study provides valuable insights into the career paths of track cyclists, the validity of currently available performance indicators, and the discrepancies between data analysis and coaches' opinions. These results can serve as a framework for coaches, federations, and applied researchers in their pursuit of talent identification and development in track cycling. By acknowledging the complexity and diversity within this sport, our findings underscore the importance of a holistic approach that surpasses performance metrics alone.

### *Key Takeaways*

- Riders excelling in both the junior (top 10%) and elite categories are uncommon.
- UCI points and junior classifications have limited predictive value for future success.
- Superior performance in the junior categories is a more reliable indicator in sprints than endurance track cycling disciplines.
- Coaches and practitioners should focus on nurturing junior athletes' long-term development toward the elite level rather than chasing short-term results.
- Discrepancies in biological age can hinder talented male sprint riders during their junior years.
- The importance placed on early performance varies depending on the gender and the discipline.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app14073125/s1>, Supplementary File S1: Correlation of the variables with the dimensions of the Principal Component Analysis; Supplementary File S2: Influence of the Relative Age Effect on the median Average Corrected Score.

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