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Performance trajectories of Italian professional cyclists: an analysis of the influence of youth performance on professional success

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ABSTRACT

The aim of the study was to analyse individual performance trajectories of professional (PRO) Italian cyclists across their careers. It sought to compare the performance progression of successful and unsuccessful PRO cyclists, analyse the best predictors of success in PRO cyclists and explore whether the relative age effect (RAE) influences PRO success. The national ranking positions gathered in the youth (U19 and elite/U23) and the PRO categories were retrieved for every year of competition of 81 PRO Italian cyclists and retrospectively analysed. Participants were divided in successful and unsuccessful, depending on whether they reached at least once the top 400 positions in the PRO ranking or not. Successful PRO cyclists display better youth ranking positions and tend to spend less time in youth categories, transition to the PRO category at an earlier age, reach their best PRO ranking at an older age compared to unsuccessful PRO cyclists. The best youth ranking, the age of the best PRO ranking and the years spent in youth categories are all predictors of PRO success. For every additional year spent in youth categories, there are 50.8% less odds of becoming a successful PRO cyclist. RAE does not affect Italian cyclists' PRO success.

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1. Introduction

In recent years, talent identification – the process of recognising athletes with the potential to excel in a particular sport – has become a topic of great interest across various sports, where youth talent identification programs have been strongly supported by federations, professional teams, and sponsors, hence gaining popularity (Abbott & Collins, 2002; Johnston et al., 2018; Vaeyens et al., 2009). Although an exhaustive definition of talent is currently lacking, it is commonly accepted that talented young athletes display superior athletic performance compared to their peers and thus have the potential to reach top-level performance in their discipline (Breitbach et al., 2014;

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Johnston et al., 2018). In this regard, the process of talent identification has lately assumed a crucial role in identifying, promoting, supporting, and developing youth athletes who display the skills and the potential to become top sports performers (Pruna et al., 2018).

Talent development – the progression of an athlete's performance – involves the interplay of factors related to the athlete (i.e. maturation, anthropometric measures, physiological, psychological, technical, and tactical skills), the environment (i.e. parental, coaching and training support), and chance (Elferink-Gemser et al., 2011). The talent development process occurs non-linear and dynamic, making the long-term prediction of success challenging (Abbott et al., 2005). Several studies reported that success as a junior athlete does not guarantee athletic success in adulthood in tennis, volleyball, judo, track and field, and swimming events (Barreiros et al., 2014; Boccia et al., 2019, 2021; Brustio et al., 2022; Li et al., 2020; Pizzuto et al., 2017; Vaeyens et al., 2009). Recently, in road cycling opportunities were explored for using a data-driven approach to identify talents based on results in youth categories (Janssens et al., 2023). Talent identification has mainly focused on physiological features such as overall oxygen uptake (Menaspà et al., 2010) and power output-related measures (Larson & Maxcy, 2016), which require costly and time-consuming procedures.

Some studies reported that professionals (PRO) outperformed non-professional cyclists in the U17, U19, and U23 categories (Cesanelli et al., 2022; Gallo, Mostaert, et al., 2022; Mostaert et al., 2022). Successful ranking in these categories increased the probability of becoming a PRO cyclist, with ranking in the first year as a U23 representing the best predictive value of future success (Gallo, Mostaert, et al., 2022). Moreover, being successful in the U17 and U19 categories further increased the odds of competing in the World Tour as an adult (Mostaert et al., 2022; Svendsen et al., 2018). Hence, current literature suggests that success in youth categories increases the odds of becoming a PRO cyclist.

Few studies investigated the career transition rates from the youth to the senior categories in cycling (Cesanelli et al., 2022; Schumacher et al., 2006). Schumacher and colleagues (Schumacher et al., 2006) reported that only 30% of cyclists who took part in the Junior World Championship (U19) competed in the World Championship as adults. Moreover, only 34% of the participants in the Junior World Championship participated in future elite competitions, indicating that transition rates from youth to senior categories are low (Schumacher et al., 2006). A recent study on Italian cyclists reported that the U16 and U18 transition rates to the UCI World Tour were 15% and 38.8%, respectively, while the transition rate increased up to 65% for the U23 category (Cesanelli et al., 2022).

Nonetheless, further analysis is needed to assess whether transition rates vary between successful and less successful PRO cyclists and whether relative age effect (RAE) – an asymmetry in the birth distribution with an over-representation of athletes born close to the selection date – influences such transition rates. Most studies tracked cyclists' success only until the beginning of their professional career, without considering how success varies in professional categories. It is not clear whether youth success is associated with better performance in the long term.

The relationship between age and peak performance in PRO cyclists has been recently investigated both in men (Kholkine et al., 2023) and women (de Leeuw & Kholkine, 2024). However, there is a paucity of literature investigating the

relationships between cyclists' success during their entire career and corresponding performance in youth categories. A longitudinal approach, tracking athletes' ranking over their whole career, would allow the assessment of performance differences between PRO cyclists who are top performers and professional cyclists who are not. Again, PRO cyclists have limited knowledge regarding the relationship between birthdates and successful transition from the junior-to-senior levels, which should also be considered to evaluate how RAE is rooted.

This study aimed to analyse the individual performance trajectories of PRO Italian cyclists across their careers. First, we assessed whether cyclists' birthdates influenced PRO success. Second, we analysed the best predictors of success of successful PRO cyclists. Then, we compared the performance progression of cyclists who achieved (successful) and not (unsuccessful) the top 400 ranking as PRO. Finally, we assessed the best predictors of performance for successful cyclists.

Based on previous research, we hypothesise that RAE does not influence PRO success (Gallo, Mostaert, et al., 2022; Mostaert et al., 2022). Considering performance progression, we would expect successful PRO cyclists to reach the PRO category earlier than unsuccessful.

2. Materials and methods

2.1. Participants

Youth and professional ranking positions of Italian professional cyclists were collected on two public online databases Ciclismo.info and Procyclingstats, respectively (http://www.ciclismo.info; https://www.procyclingstats.com). On the one hand, the database Ciclismo.info reported cyclists' yearly youth placing for all national categories based on national race results (http://www.ciclismo.info). On the other hand, the database Procyclingstats outlined PRO cyclists' yearly placing, obtained from UCI international results (https://www.procyclingstats.com).

Data were collected for each competitive season of cyclists born between 1990 and 1995. This period was selected for two reasons. First, youth ranking position was reported on the online database (http://www.ciclismo.info) only for cyclists born in 1990 and younger. Second, youth ranking position was collected for athletes born until 1995 to ensure that athletes had the chance to compete for at least 1 year in the professional category. In fact, the database revealed that cyclists entered the PRO category at the age of 23.

Having Italian citizenship was the main inclusion criterion. For youth categories (U19 and elite/U23), being affiliated with a team of the Italian national federation was an additional inclusion criterion, while having competed for at least 1 year in the professional category was an additional inclusion criterion for professional cyclists. Exclusion criteria were to have not finished the professional cycling career at the time of the analysis. After the inclusion and exclusion criteria were verified, we were left with a final sample of 81 cyclists.

2.2. Experimental design

Success in youth categories (U19 and elite/U23) was retrospectively assessed based on ranking position in the annual Italian national ranking of the Italian Cycling Federation, retrieved from the online database Ciclismo.info (http://www.ciclismo.info). Occasionally, cyclists' ranking position was not reported on the database for one or more competitive seasons. To provide continuity to the data set, whenever there was a gap in the ranking position, the very last ranking position of the competitive year was reported for the athlete. The year each athlete started competing as a professional was verified, and the ranking position for each year competing as a professional cyclist was retrieved from the online database Procyclingstats (https://www.procyclingstats.com).

The total of years competing in the U19, elite/U23, and professional categories were respectively counted. Transition rates, which indicate the proportion of cyclists who reached the top 400 ranking in the professional category, were calculated. Participants were then divided into two groups based on transition rates. Cyclists who reached the top 400 ranking at least once in the professional category were classified as successful (n = 22), while cyclists who did not reach the top 400 ranking as professionals were classified as unsuccessful (n = 59).

Cyclists' birthdates were split into four quartiles: January–March (Q1), April–June (Q2), July–September (Q3), and October–December (Q4). Quartile birth month distribution for the whole sample and successful cyclists was assessed. Then, transition rates of successful cyclists from the youth to the professional categories were calculated based on the date of birth distribution across quartiles. Since data were collected using publicly available online resources, no informed consent was obtained before this study. The study design and procedures were approved by the local ethics committee. This study was conducted according to the declaration of Helsinki.

2.3. Statistical analysis

The difference in birth distribution across quartiles between the whole sample and successful professional cyclists was investigated using chi-square (χ^2). Expected uniform quartile distributions (i.e. 25% for each quartile) were used as reference. Cramer's V effect sizes were calculated. Threshold values for Cramer's V were $V \leq 0.06$ trivial effect, $0.06 < V \leq 0.17$ small effect, $0.17 < V < 0.29$ medium effect and $V \geq 0.29$ large effect.

The transition rates from junior to professional categories were calculated using a binomial proportion confidence interval [95% CI]. Similarly, the same approach was used to calculate the quartile transition rate.

Career progressions of successful and unsuccessful professional cyclists were compared using independent t-tests. This kind of analysis was carried out for the mean best youth ranking, the age of best youth ranking, years spent in the youth categories, years spent in the U23 category, and age of transition to the professional category. The effect sizes (ES) for independent samples t-tests are reported as Cohen's d using the small = 0.2–0.5, medium = 0.5–0.8, and large ≥0.8 Cohen ranges (Wassertheil & Cohen, 1970). Homogeneity of variance was tested for all variables by Levene's test of homogeneity. Bivariate logistic regression with a logit link was implied to assess the odds ratios and the

95% confidence intervals of becoming a successful professional cyclist based on the best youth ranking, the age of the best PRO ranking, and years spent in the youth categories. As ~50% of the sample reached their best youth ranking at aged 18, we excluded the variable age of junior best performance for this kind of analysis. Input variables of the model were checked for multicollinearity and variance inflation factors indicate this was not an issue for the analysis.

Data processing was performed using custom-written software in MATLAB R2023a (MathWorks, Natick, MA). Data were analysed using the statistical software Jamovi version 2.3 (Jamovi – Open Statistical Software). The graphs were made with GraphPad Prism 9 (Prism – GraphPad). The significance level was set at 0.05.

3. Results

In Table 1, descriptive data stratified by all sample, successful, and unsuccessful cyclists, are reported for all the variables considered. Table 2 displays birth distribution across quartiles for all sample and successful PRO cyclists. Considering the whole sample, athletes' birth distribution across quartiles is not significantly different ($p = 0.130$; V = 0.15). Birthdate distributions of successful PRO cyclists did not significantly vary across quartiles either ($p = 0.881$; V = 0.10). Considering the whole sample, 32.0% of the cyclists were born in Q3, 30.9% in Q1, 19.8% in Q2, and 17.3% in Q4. The most successful PRO cyclists are born in Q1 (31.8%), while most unsuccessful PRO cyclists are born in Q2, Q3 and Q4.

The transition rate of successful PRO cyclists from the youth to the professional categories is 27.2% [17.9, 38.2]. When analysed by quartiles, the transition rate is 28.0% [12.1, 49.4] for cyclists born in Q1, 31.3% [11.0, 58.7] for cyclists born in Q2, 19.2% [6.6, 39.4] for cyclists born in Q3, and 35.7% [12.8, 64.9] for cyclists born in Q4.

The best ranking obtained in youth categories (U19 and elite/U23) is significantly better in successful PRO cyclists compared to unsuccessful PRO cyclists ($p < 0.001$; ES = 0.64; Figure 1a). The age of the best PRO ranking tends to be higher for successful PRO

Table 1. Descriptive data stratified by all sample, successful and unsuccessful cyclists.

	All sample			Successful			Unsuccessful		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Best youth ranking (U19 and elite/U23)	81	23.8	28.5	22	11.0	20.9	59	28.6	29.7
Age of best youth ranking (U19 and elite/U23)	81	19.8	2.6	22	19.7	2.4	59	19.8	2.7
Age of best PRO ranking	81	24.5	2.2	22	25.1	2.3	59	24.2	2.1
Years in youth categories (U19 and elite/U23)	81	6.3	1.7	22	5.8	1.2	59	6.5	1.8
Years in U23	81	4.3	1.6	22	3.8	1.2	59	4.4	1.7
Age of transition to PRO	81	23.3	1.7	22	22.8	1.2	59	23.5	1.8

Table 2. The percentage difference in birth distribution across quartiles between all the sample and successful cyclists.

	Q1	Q2	Q3	Q4	χ^2	P	Cramer V
All sample ($n = 81$)	30.9	19.8	32.0	17.3	5.650	0.130	0.15
Successful ($n = 22$)	31.8	22.7	23.0	22.7	0.667	0.881	0.10

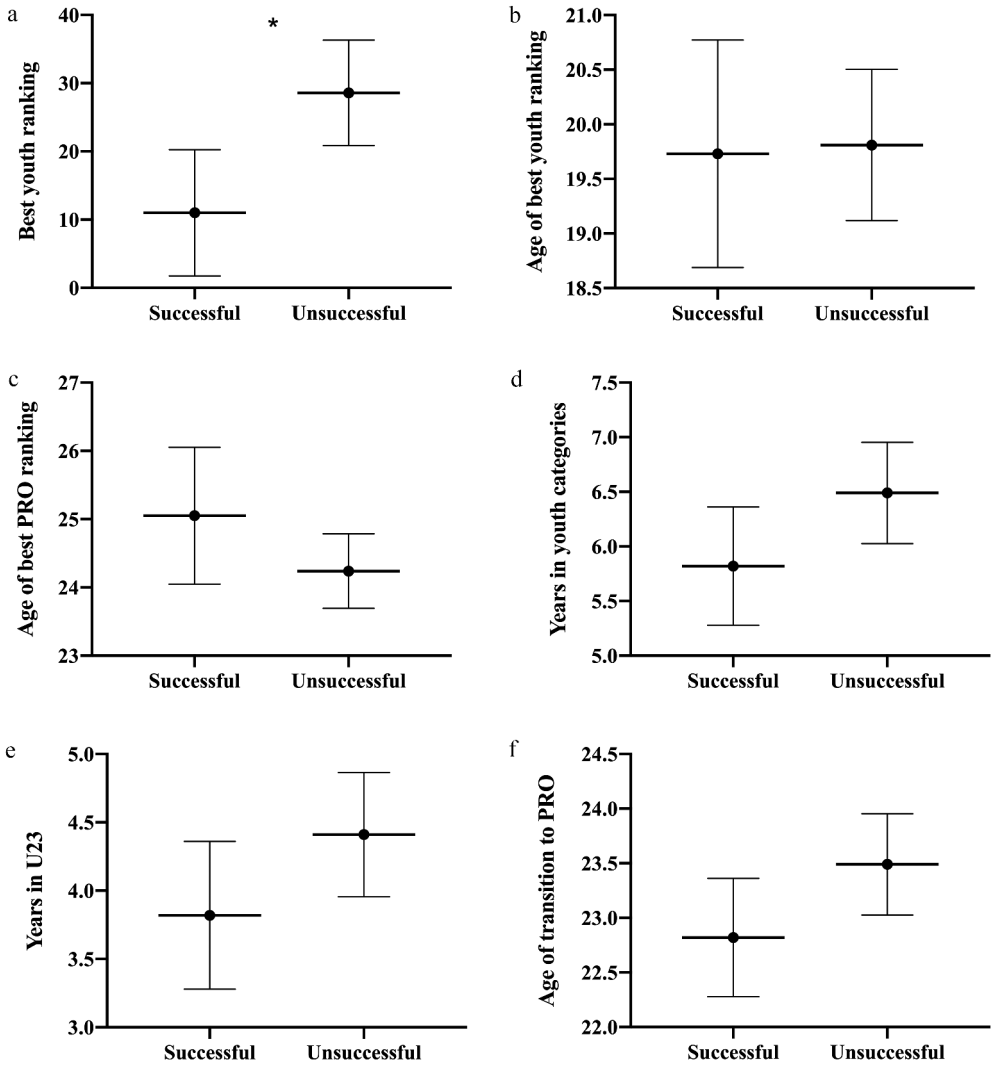

Figure 1. Mean (± SD) difference between successful and unsuccessful PRO cyclists in best youth ranking (U19 and elite/U23), age of best youth ranking (U19 and elite/U23), age of best PRO ranking, years in youth categories (U19 and elite/U23), years in U23 category, age of transition to PRO. * $p < 0.05$.

cyclists than unsuccessful PRO cyclists ($p = 0.133$; ES = 0.38; Figure 1c). Successful PRO cyclists tend to spend less years competing in youth categories compared to unsuccessful PRO cyclists ($p = 0.105$; ES = 0.41; Figure 1d). Successful PRO cyclists tend to spend less time in the U23 category compared to unsuccessful PRO cyclists ($p = 0.150$; ES = 0.36; Figure 1e). Unsuccessful PRO cyclists tend to transition to the PRO category at an older age compared to successful PRO cyclists ($p = 0.105$; ES = 0.41; Figure 1f).

Table 3 displays data obtained from bivariate logistic regression with odds ratio related to the following variables: best youth (U19 and elite/U23) ranking, age of best PRO ranking, and years in youth categories. All the mentioned variables significantly predict

Table 3. Bivariate logistic regression with odds ratio of best youth ranking (U19 and elite/U23), age of best PRO ranking, and years in youth categories (U19 and elite/U23).

		95% confidence interval					
	Estimate	Inferior	Superior	SE	Z	P	Odds-ratio (95% CI)
Best youth ranking (U19 and elite/U23)	−0.031	−0.0062	−0.000	0.016	−2.01	0.045	0.97 [0.94, 1.00]
Age of best PRO ranking	0.490	0.104	0.876	0.197	2.49	0.013	1.63 [1.11, 2.40]
Years in youth categories (U19 and elite/U23)	−0.709	−1.250	−0.168	0.276	−2.57	0.010	0.49 [0.29, 0.85]

PRO success ($p = 0.045$; $p = 0.013$; $p = 0.010$, respectively). Taking the best youth ranking into account, for every additional worse ranking position, there are 3.1% less odds of becoming a successful PRO cyclist. Considering the age of the best PRO ranking, for every additional year, there are 63.2% more odds of becoming a successful PRO cyclist. For every additional year spent in youth categories, there are 50.8% less odds of becoming a successful PRO cyclist.

4. Discussion

The current study aimed to analyse individual performance trajectories of PRO Italian cyclists across their careers and to identify the main predictors of successful PRO performance. The main finding of the study is that successful PRO cyclists outperform unsuccessful PRO cyclists in youth categories (U19 and elite/U23). Best youth ranking, age of best PRO ranking, and years in youth categories are seem to be related to the probability of becoming a successful PRO cyclist. A better youth ranking position and reaching the best PRO ranking position at a relatively older age are associated with higher odds of becoming a successful PRO cyclist. Finally, RAE does not influence PRO success.

4.1. Differences between successful and unsuccessful PRO cyclists

Successful Italian PRO cyclists display better-ranking positions in youth categories and tend to spend fewer years in the youth categories, reach their best youth ranking position earlier, transited to PRO categories at a relatively younger age than unsuccessful PRO cyclists. This is in line with Mostaert and colleagues (Mostaert et al., 2022), who found in cycling that future achievers outperform future non-achievers starting from U17 onwards. In support of this, Menaspà and colleagues (Menaspà et al., 2010) reported that Italian cyclists in higher positions in the U19 Italian national ranking display higher physiological characteristics than cyclists placed lower.

Our findings contrast with a further investigation on other endurance sports, such as athletics middle- and long-distance events, which revealed that early success does not contribute significantly to predicting or explaining senior success (Pizzuto et al., 2017). However, it is worth mentioning that results from the study by Pizzuto and colleagues

(Pizzuto et al., 2017) were drawn from a sample including athletes specialised in distances going from 800 m to 10,000 m. When considering only athletes specialised in longer endurance events such as 10,000 m, there seems to be a certain degree of continuity between successful performance in youth and senior categories (Pizzuto et al., 2017).

A study by Schumacher (Schumacher et al., 2006) reported that only 29.4% of elite athletes had participated in the Junior World Championship. In comparison, only 34% of the participants in the Junior World Championship participated in major elite competitions afterwards (Schumacher et al., 2006), suggesting that success in youth categories is not a necessary condition for later success. However, the study by Schumacher and colleagues (Schumacher et al., 2006) might have underestimated the number of successful athletes in youth categories, considering that the Junior World Championship represents a tight selection criterion that sets a limit of six athletes recruited per nation. When considering junior elite athletes' success over the long term, it becomes more evident that podium finishers or winners in youth categories are more successful than cyclists who had only participated in the Junior World Championship (Schumacher et al., 2006). Combining our findings with the previously cited studies, being an early achiever is associated with a successful PRO career in cycling.

4.2. Predictors of successful PRO performance

Among our findings, it is particularly interesting that for every additional year of age at the moment of reaching the best PRO ranking, there are 63.2% more odds of becoming a successful PRO cyclist. This result could be explained by the tendency of top PRO athletes to have longer careers compared to unsuccessful PRO athletes (Baker et al., 2019). Furthermore, assuming comparable physiological qualities in the PRO category, a successful cycling performance requires significant mental qualities and tactical skills, which may need considerable time to develop and consolidate (Lucia et al., 2001). In support of this, several studies reported that experience, tactical skills, and race preparation strongly influence road cycling performance. In contrast, physiological and motor skills are stronger performance determinants in shorter performances, such as track cycling (Capelli et al., 1998; Craig et al., 1993).

Our findings show that for every additional year spent in youth categories, there are 50.8% less odds of becoming a successful PRO cyclist, suggesting that successful PRO cyclists tend to display a quicker transition across categories. Successful cyclists' quicker transition across youth categories could be related to higher physiological parameters compared to unsuccessful youth cyclists, as previously reported by several studies (Menaspà et al., 2010; Svendsen et al., 2018). Moreover, this is in line with findings by Kholkine and colleagues, who reported that road cycling PRO peak performance occurs around 27 years of age (Kholkine et al., 2023). Taken together, these findings suggest that a performance peak reached later in the PRO career and a quick progression across categories are associated with higher chances of becoming a successful PRO cyclist.

4.3. Influence of RAE on PRO success

Successful and unsuccessful PRO cyclists are equally distributed across birth quartiles, suggesting that RAE does not influence Italian cyclists' PRO success. This is in line

with a study by Mostaert and colleagues (Mostaert et al., 2022) on Belgian cyclists, who reported a gradual decline in the effect of RAE while progressing towards adulthood. In recent years, talent identification – the process of recognising athletes with the potential to excel in a particular sport – has become a topic of great ward adulthood. With the present investigation, we found that RAE does not influence PRO success.

In line with previous studies reporting that the effect of RAE disappears in adulthood (Gallo, Mostaert, et al., 2022; Mostaert et al., 2022), our findings reveal that RAE does not influence PRO success. Once they reach the PRO categories, cyclists display similar physiological characteristics and accumulated volumes of training (Gallo, Mateo-March, et al., 2022): hence, it can be argued that mental and tactical qualities are the main determinants of successful PRO performance (Menaspà et al., 2013; Phillips & Hopkins, 2020). Psychological factors such as mental and tactical skills appear to significantly influence long-distance endurance events, compared to short-distance events, in which strength level and maturational status play a major role (Capelli et al., 1998). Hence, it could be that the effect of RAE varies based on cycling specialities, possibly with sprinters being more affected by RAE. Further research should focus on identifying whether RAE varies based on cycling speciality.

4.4. Limitations

Despite considering athletes' performance trajectories across their whole careers, the present study has some limitations. The online database used to retrieve youth ranking positions only reported data from 2007. This considerably affected our sample size, as it was impossible to collect youth data for cyclists born earlier than 1990. Moreover, we did not consider the cyclists who did not achieve the PRO level, this means that there might be some early achievers who did not manage to transition from youth to senior categories.

5. Conclusion

The present study confirmed some previous findings on the prediction of success up to the beginning of the PRO career in Belgian and Italian cohorts; however, it took it a bit further by assessing success across athletes' whole career. The top Italian PRO cyclists already outperform unsuccessful PRO cyclists in the U19 and elite/U23 categories, suggesting that talent identification and selection should mainly focus on the performance obtained in these categories. Successful cyclists reach their best PRO ranking at an older age. Youth competition success and a quick transition across categories increase the odds of becoming a top Italian PRO cyclist. Hence, progressive but not too slow performance growth is what we suggest looking for in athletes competing in the U19 and elite/U23 categories. Finally, RAE does not affect success in the PRO category. Our analysis suggests that being an early achiever is associated with becoming a successful PRO cyclist, and we believe such findings can be helpful to coaches and governing bodies to improve talent identification and selection in road cycling.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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