Is motor coordination the key to success in youth cycling?

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Keywords:	(non-)sport-specific test battery, road cycling, youth categories, talent prediction, longitudinal study

ABSTRACT

Purpose: To evaluate the predictive value of a (non-)sport-specific test battery on the future success of young cyclists, test scores were compared to the competition performances two to three years later. **Methods:** Three motor coordination, five physical performance, and two cycling-specific measurements were collected in 111 U15 (13.0 – 14.9 years) and 67 U17 (15.0 – 16.9 years) male road cyclists. In addition, maturity status and relative age were assessed. National and provincial competition results two to three years later, in the $U17_{year2}$ and $U19_{year2}$ categories, were submitted to two separate four-stage hierarchical regressions. **Results:** The results of the model of the U15 group revealed that maturity, relative age, motor coordination, physical performance, and cycling-specific performance accounted for 22.6% of the variance in competitive success. For the U15 category, only maturity and motor coordination were significant predictors of competitive success in the $U17_{year2}$ category. Maturity and motor coordination each uniquely explained ±5% of the variance. However, for the U17 group, neither maturity, relative age, motor coordination, physical performance, nor cycling-specific performance could predict competitive success in the $U19_{year2}$ category. **Conclusions:** The current study underlines the importance of general motor coordination as a building block necessary for optimal development in youth cycling. However, considering the lack of predictive value from the U17 category onwards, other features may determine further development of youth athletes. Nevertheless, it argued why athletes need to possess a minimum level of all physical, motor coordination, and cycling-specific characteristics to experience success and enjoyment in their sport.

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INTRODUCTION

As is the case for all sports, in cycling, sports institutions and (inter)national federations are responsible for providing athletes the possibility to enjoy their sport in a recreational and/or competitive way. They are facing the challenge of '*developing healthy, capable and resilient young athletes, while attaining widespread, inclusive, sustainable and enjoyable participation and success for all levels of individual athletic achievement'* (stated by Bergeron, Mountjoy, Armstrong, Chia, Côté, Emery, Faigenbaum, Hall, Kriemler, Léglise [1]). An effective integrated approach to athlete development in competitive athletes begins with an assessment of potential talent, followed by a structured training/development programme [1-3]. However, identifying potential in youth athletes is difficult and requires further insights into the performance characteristics and athletic profile of cyclists.

Within road cycling, competition results are frequently used as the main criterion to identify and select youth cyclists as potential cyclists [4-6]. For example, the predictive value of youth competition results from the U17, U19, and U23 category onwards was recently studied and confirmed, with the highest success rates reported in the second year of the categories [5-7]. However, competitive success in the U15 category could not differentiate future achievers from future non-achievers, nor predict future performance at the senior elite level [6]. Consequently, since competition results alone do not seem to be a sufficient indicator of future success in the U15 category, other factors may contribute to competition outcomes in the younger categories. These findings are in line with the results of Staff, Gobet, Parton [8], who indicated that the traditional talent identification method, using achievement measures, expert assessment of performance by coaches, and talent scouts at an early age, is inferior to a detection talent identification methodology based on a range of generic physical and skill based tests between the ages of 11 to 16 years. This underlines the need for a multidimensional approach to talent identification in cycling.

Morphological and physiological features have been commonly tested in function of talent identification in road cycling [9]. In both youth (U17-U19) and professional (U23 – elite level) cyclists, success is related to high levels of physiological characteristics [5,10-19]. However, the traditional physiological measures of aerobic fitness that differentiate high- from low-level youth (U19) cyclists do not predict their future competitive level in adulthood [20]. The lack of predictive validity of these measures of aerobic fitness is probably mainly due to the multifactorial nature of cycling performance [20]. Besides VO_{2max}, which is considered a prerequisite in road cycling, other sport-specific tests measuring, e.g., technical skills should be further investigated in youth cycling [9,20].

Skill-based tests, such as general motor coordination tests seem able to discover the athlete's real potential to pick up new technical skills [21-23]. In other sports such as gymnastics, soccer, and volleyball, this low-resource assessment approach has been related to future success in sports [24]. Recently, Mostaert, Laureys, Vansteenkiste, Pion, Deconinck, Lenoir [25] showed that general motor coordination (measured using the KTK3 test battery), in combination with measures of anthropometry, physical performance, and cycling-specific tests, could accurately (80,7%) discriminate between young adult athletes of different cycling disciplines. However, it is not clear if motor coordination could also contribute to talent identification in youth cycling. Although motor coordination has been shown to benefit coaches and federations when evaluating young/adult athletes [26], future research is needed within youth cycling athletes.

It is generally known that the selection process of potential youth athletes is biased by the young athlete's maturational timing and relative age [27], especially in sports that strongly rely on characteristics such as speed, strength, and power [28]. Children who mature earlier and/or are relatively older than their peers, benefit from a margin in body size and physiological development, and could therefore falsely be identified as more potential than their peers [28,29]. However, after puberty (i.e. around the age of 17 years for boys), maturity and age-related differences are reduced and largely eliminated in non-athletes and athletes [28,30,31]. Similar results were found for road cycling as the relative age effect (RAE) was present in the U15 category, but seems to fade away as athletes reach the U19 category [6]. In the U19 category, the athletes reached adulthood which may explain that the RAE on inter-individual differences may decrease [2,32]. Becoming physically and mentally stronger at a later age might be of a greater importance in endurance sports to develop into successful adult elite athletes [4,6]. Therefore, it is suggested that future research should consider both the RAE and maturation in youth cycling research, especially when they affect parameters that are crucial in identifying and selecting young athletes.

The purpose of this study was to examine if a (non-)sport-specific test battery has a predictive value for the competition results of youth cyclists two to three years later. It is hypothesised that the motor coordination, physical, and cycling-specific tests are predictors for future performance.

METHODS

Participants

In collaboration with the Flemish Cycling Federation (Cycling Vlaanderen), five test days per year were organised to identify and monitor young competitive cyclists. A sample of 620 male road cyclists participated in the test days between 2015 and 2017. Of those, 372 cyclists were between 13.0 and 16.9 years of age (in the U15 or U17 category). Next, excluding partial test results and duplicates resulted in a total sample of 306 cyclists (Figure 1). Only the 111 cyclists who performed the test battery between 13.0 - 14.9 years of age (U15), and competed in at least one of the selected provincial and/or national competitions in the second year of the U17 category (two to three years later) were included in the first cohort. The second cohort consisted of 67 male road cyclists who performed the test battery between the age of 15.0 - 16.9

years (U17), and registered at least one competition result in the second year of the U19 category (two to three years later). The study was conducted in accordance with the Helsinki Declaration and was approved by the Ethics Committee of the Ghent University Hospital under registration no. PA 2016/021.

“[insert Figure 1.]”

Procedure and measurements

Prior to testing, anthropometric measurements body height, weight, and sitting height measurements were assessed to estimate the biological maturity using a sex-specific regression equation [33]. Age of peak height velocity (APHV; years) was applied in the analyses. Additionally, the relative age effect (RAE) was also included in the statistics. Within road cycling, an annual age-grouping competition strategy from January until December is used. For the purpose of this study, the athletes were divided into four birth quarters according to their month of birth in relation to the yearly cut-off date to examine the birth date distribution and relative age effect (RAE): Q1: January – March, Q2: April – June, Q3: July – September, Q4: October – December. Furthermore, the cyclists completed 10 (non-)sport-specific tests, consisting of five physical, three motor coordination, and two cycling-specific measurements. The data were collected at the same indoor venue and assessed by a team of 10 to 12 experienced examiners affiliated with Ghent University. The athletes performed the tests barefooted with the exception of the sprint, endurance shuttle run, and cycling-specific tests. The barefooted tests were performed in a randomised circuit manner, followed by a short warm-up (running, acceleration, and active stretching exercises) in order to perform the sprint, shuttle bike, endurance shuttle run, and maximal cadence test, respectively. To assess if the (non-

)sport-specific test battery could indicate competition performance, race results from national and provincial competitions were retrospectively collected [34,35].

Motor coordination tests

To evaluate general gross motor coordination, the Körperkoordinationstest für Kinder (*KTK3*) test battery was used [36-39]. The first subtest was moving sideways (MS) on a straight-line handling two wooden platforms for 20 seconds (sum of two attempts). The second subtest was jumping sideway (JS) performing two-legged jumping over a wooden slat for 15 seconds (sum of two attempts). The third subtest was walking backwards (BB) along a balance beam of 6 cm, 4.5 cm, and 3 cm wide (sum of three trials on each balance beam, with a maximum of 8 steps per trail). The KTK3 test battery has a good reliability and validity, shown by a test-retest reliability ranging from 0.80 to 0.95 for the specific subtests [38,40,41].

Physical performance tests

The best performance of two trials on the standing broad jump (*SBJ*), which measures the explosive leg power of the participants, was registered (to the nearest 1 cm) [42]. To assess the hamstring and lower back flexibility, a sit and reach (*SAR*) was performed (to the nearest 0.5 cm; the best score of two trials) [42]. Core muscle endurance was determined using an *endurance plank test* by executing a plank position for as long as possible (one trial, to the nearest 1 s) [43,44]. The best time of two trials on the *30-meter sprint* test, which measures speed, was registered (accuracy of 0.001 s, MicroGate Racetime2 chronometry and Polifemo Light Photocells; MicroGate, Italy) [45]. Cardiovascular endurance was obtained by a 20-meter endurance shuttle run test (*ESHR*), to the nearest 0.5 min [42]. The test-retest reliability and validity has been described elsewhere [42,45]

Cycling-specific tests

The procedures of the cycling-specific shuttle bike and maximal cadence test are in accordance with the test procedures described in the study of Mostaert, Laureys, Vansteenkiste, Pion, Deconinck, Lenoir [25]. To assess agility and cycling skills, a *shuttle bike test* was performed on a BMX bicycle (2 different sizes depending on body height). The riders needed to complete an eight-shaped circuit as quickly as possible without hitting the markers and without losing control over the bicycle. The shuttle bike test was performed twice, with the best time used for analyses. The time was recorded using time gates (accuracy of 0.001 s, MicroGate Racetime2 chronometry and Polifemo Light Photocells; MicroGate, Italy). The shuttle bike test has an intra-class correlation of 0.763 (95% CI 0.440 – 0.899) [25].

Agility was assessed using a *maximal cadence test,* performed on a calibrated Flanders SR1 Ultimate racing device or standardised SRM cycle ergometer (SRM - Schoberer Rad Messtechnik; Germany). Athletes with a body height of > 1,55 m performed the test on the SRM cycle ergometer. The cyclists began in a flying start (resistance 1) while seated and with their hands placed on the drop handlebars. For ten seconds the athlete had to perform their maximal cadence. The highest score (peak frequency) was recorded for one attempt. The maximal cadence test has an intra-class correlation of 0.936 (95% CI 0.863 – 0.970) [25].

Competition results

As an outcome variable, the competitive performance level was determined. Results from four national (Belgian championship road and time trial, and two national climb races) and two provincial competitions (provincial championship road and time trial) were retrospectively gathered [34,35]. The competitive performances of the first cohort were determined at the time the cyclists were active in the $U17_{year2}$. For the second cohort, the competitive performances in the $U19_{year2}$ were established. To set the actual overall performance level of the cyclists, scores were given according to the place achieved for each competition (in line with Mostaert, Gallo, Faelli, Ruggeri, Delbarba, Codella, Vansteenkiste, Filipas [7]). As participation in national competitions is only authorised for the best competitors from each province, the national championships results weighed double compared to the provincial championships (Table 1).

"[insert Table 1]"

Data analysis

The data were analysed with SPSS Statistics version 25. Descriptive statistics were assessed and there were no outliers in the data. Standardised z-scores were calculated with the following formula, using means and standard deviations for each age group (13, 14, 15, and 16 years) and test item [26]:

$$z - score_{test} = \frac{(rawscore_{test} - mean_{test})}{standarddeviation_{test}}$$

Overall mean z-scores were calculated for all tests and averaged for the three performance categories; i.e., physical performance (i.e. z-scores from SBJ, SAR, plank test, 30m sprint, and ESHR), motor coordination (i.e. z-scores from jumping sideways, moving sideways, and balance beam) and cycling-specific performance (i.e. z-scores from shuttle bike and maximal cadence). Prior to conducting a hierarchical multiple regression, the relevant assumptions of this statistical analysis, such as multicollinearity, normality of residuals, homoscedasticity, linearity, and independence of errors, were tested [46]. A four-stage hierarchical regression analysis was performed separately for the U15 and U17 groups to explain the variance of the outcome variable, competitive performance level. APHV and RAE were entered at stage one of the regression. Motor coordination was included at stage two, physical performance at stage three, and cycling-specific performance at stage four. Statistical significance, size, direction of the standardised regression coefficients, and change in R-square were reported. For all analyses, the significance level was set at a p-value of < 0.05.

RESULTS

Performance prediction in the U17 category

Descriptive statistics are presented as mean ± standard deviation (SD) in Table 2. The four-stage hierarchical regression statistics are displayed in Table 3 and Figure 2. The results revealed that at stage one the model accounted for 7.8% of the variance in competition results for APHV and RAE. APHV was the only significant predictor uniquely explaining 7.5% of the variance. Adding motor coordination revealed a significant predictive relationship between motor coordination and future competitive success (accounted for 20.5% of the variance). Motor coordination uniquely explained an additional 12.8% of the variance in competitive success. Introducing physical performance and the cycling-specific tests in the third and final stage, respectively, did not increase the variance in competitive success. The full model, including APHV and RAE, and all three performance variables, was statistically significant ($F_{(5,105)} = 6.131$; $p < 0.001$) and accounted for 22.6% of the variance in competitive success.

"[insert Figure 2.]"

"[insert Table 2.]"

"[insert Table 3.]"

Performance predictions in the U19 category

The four-stage hierarchical regression revealed that neither APHV, RAE, motor coordination, physical performance, nor cycling-specific performance in the U17 category could predict competitive success in the $U19_{year2}$ category ($F_{(5,61)}=0.521$; $p=0.759$; $R^2=0.041$). The descriptive statistics and results from the hierarchical regression are displayed in Table 2, Table 4, and Figure 3, respectively.

"[insert Figure 3.]"

“[insert Table 4.]”

DISCUSSION

The present study offers a better understanding of the usefulness of a (non-)sport-specific test battery for young cyclists, to predict competition performance two to three years later. Results showed that a (non-)sport-specific test battery performed in the U15 accounted for 22.6% of the variance in the competition performance as a U17 athlete. The findings underline the importance of maturity and general motor coordination in youth cycling, each of which uniquely explained ±5% of the variance. However, in the U17 category, neither the APHV, RAE, motor coordination, physical performance, nor cycling-specific performance could predict competitive success in the $U19_{year2}$ category.

In the U15 category, the best predictions on future success could be made based on the full model, consisting of maturity and RAE, motor coordination, physical performance, and cycling-specific performance. These findings confirm research by Staff, Gobet, Parton [8], indicating that identifying athletic potential based on a range of generic, physical, and skill-based tests is beneficial within talent research. The results showed that within youth road cycling it is important to consider the possible impact of maturity (APHV) on future race results. Earlier mature athletes are more likely to achieve better competitive results two to three years later, which is in line with the findings in previous research [47]. However, caution is warranted for coaches and federations when selecting and/or excluding athletes at this age, since the advantages that the earlier mature athletes experience may disappear after puberty [28]. A possible solution to better predict the impact of the physical ability on future success is to use bio-banding in youth athletes [48]. Bio-banding allows a better comparison between athletes of the same biological age, instead of only comparing athletes based on chronological age. Based on the findings of Mostaert, Vansteenkiste, Pion, Deconinck, Lenoir [6], a RAE was expected within the U15 category. However, within the current study RAE did not contribute to competition performance two to three years later.

Motor coordination was the only performance variable that significantly contributed to future success. Excelling in motor coordination in the U15 category resulted in a 4.7% higher chance to perform at a high level two to three years later. Similar results were found in other sports for motor coordination applying the KTK3 test battery [21,49,50]. This motor coordination test battery seems to measure a general trait underlying a wide variety of skills needed in various sports and is sensitive enough to predict future success [21,26,51]. To obtain higher motor coordination levels in athletes, previous studies suggested that athletes may benefit from early diversification including broad exposure to formal and informal play, practice and games, in both sport-specific and non-sport-specific ways [3,8]. Staff, Gobet, Parton [8] indicated that a later engagement in the development of expertise resulted in faster motor learning and development. This is in line with the previous findings of Mostaert, Laureys, Vansteenkiste, Pion, Deconinck, Lenoir [25], who suggested that there is no need for early specialisation within cycling as the different cycling profiles of high performing adolescents between 12.0 and 15.99 years of age (road, track, cyclo-cross, and mountain bike) could only be correctly discriminated for 50.1%. Accordingly, we should expect that encouraging free play, diversified training, and sports participation in the different cycling disciplines is promising for later success within cycling.

Physical performance and cycling-specific performance did not significantly contribute to the prediction of competitive success. This finding is in agreement with those of Philippaerts, Coutts, Vaeyens [52] and Vandorpe, Vandendriessche, Vaeyens, Pion, Lefevre, Philippaerts, Lenoir [21] who reported that general physical performance characteristics could determine current ability, but are less suitable as an indication for the potential to excel in the future. Moreover, training, growth, and maturation may have a possible impact on the physical variables [21,30,53], which might complicate the prediction of future performances. The cycling-specific tests consisted mainly of skill tests performed on a bicycle. Including cycling-specific tests is similar to other sports federations that focus on talent identification, who also usually include sport-specific tests (soccer: dribbling tests; gymnastics: rope skipping and climbing; volleyball: spike jump) in their test battery. The extent to which these tests can distinguish athletes of different levels and predict future performance is dependent on the sport and the type of test. However, sport-specific tests have in common that they are more subject to the training history of the athletes [54]. One might argue that, in contrast to the physical performance tests, the cycling-specific tests, similar to the soccer-specific tests (i.e. dribbling, shooting…), are less affected by maturity [22], because they mainly consist of tests with a motor component. Further research is necessary to determine if these cycling-specific tests are influenced by maturity and can measure the current ability of the athletes.

The present study was able to predict short-term cycling success over two to three years in young male road cyclists (U15). However, when applying this approach to older age groups (i.e. U17 category), it seems that a modified test battery should be developed to predict future performance. This is in line with the 'sliding populations' approach of Régnier, Salmela, Russell [55], suggesting that specific test batteries are needed for different age groups in order to predict whether athletes can or cannot reach the top level in the following age group. The current results showed that from the U17 category onwards, neither motor coordination, physical performance, nor cycling-specific performance could predict competitive success in the $U19_{year2}$ category. One reason might be the homogeneity of the current sample since the cyclists were past puberty. In parallel with the 'proficiency barrier' hypothesis in the research field of motor development [56,57], it could be assumed that at this stage in the development, the athletes need to possess a minimum level of general motor coordination to be able to experience success and enjoyment in their sport [58]. It may be possible that when athletes gain this level of development, generic testing no longer holds much or any discriminative value for athlete selection. This now means, that there is room, however, for individual profiles to vary with the perspective that they have achieved the necessary proficiency levels in these general characteristics. Another reason might be that the demands of road cycling change. Around the age of 16, cyclists begin to focus on their main discipline, a process that evolves into highly deliberate practice [59]. Furthermore, cyclists begin to compete in national and international competitions, and the distance of the races increase from the U19 category onwards (20km - 35 km in the U15 category, 60km – 80km in the U17 category, 80km - 140km in the U19 category)[5]. Therefore, it is assumed that other features may become performance determining. The systematic review of Phillips, Hopkins [9] emphasises the importance of not only focusing on the individual dimensions such as physiological, morphological, emotional, and cognitive features. Tactical features emerging from the inter-personal dynamics between cyclists, strategic features related to competition format and the race environment, and global features related to societal and organisational constraints should also be taken into account [9]. Future research is necessary to examine a more holistic approach within youth cycling, as the current test battery seems not sensitive enough to predict the cycling-specific performance at these older ages.

Despite the usefulness of these findings, some limitations should be addressed in future research. First, the current study consisted of two different cohorts, making predictions of performance two to three years later. Future research should span longer periods of longitudinal follow-up with one group of cycling athletes. This could provide additional insights into the development and the predictive value of the test battery on performance. Second, it would be valuable to include detailed information on training history and volume, using logs of deliberate practice. Third, considering the findings of Menaspa, Rampinini, Bosio, Carlomagno, Riggio, Sassi [16], who found that juniors (U19) are specialised in the same way as professional cyclists, it seems valuable to differentiate for the different road cycling specialities (uphill, flat terrain, all-terrain, and sprint riders) in the future. Finally, there is a significant potential for selection bias when selecting cyclists for the talent test days. Additionally, only cyclists who registered at least one competition result in the second year of the U17 or U19 category were included in the study. Consequently, it is suggested that the riders who experienced less success during competitions may have dropped out from cycling, and the analyses may have consisted of only the better riders from the U15 and U17 categories.

PRACTICAL APPLICATIONS

The current study provides reference values and gives a valid overview of the predictive value and usefulness of a (non-)sport-specific test battery within road cycling. These findings can aid coaches and federations when they consider (de)selection in function of talent identification. Selected youth cyclists (U15) should outperform their peers in one or more of the motor coordination, physical and sport-specific features, taking into account maturity and RAE. Special attention should be paid to the performances on the motor coordination tests and the possible impact of maturity. However, the identification of potential talent is complex [60,61]. Therefore, once the cyclists participate in the U17 category, it is suggested to use this test battery to monitor development rather than to identify potential talent.

CONCLUSION

The present study showed that a (non-)sport-specific test battery could be used within a U15 cycling population to predict future success two to three years later. Maturity and general motor coordination were the only variables that significantly contributed to future success. The findings emphasise that high levels of motor coordination in cycling can be promising for later success. Considering the reduced predictive value from the U17 category onwards, these tests alone do not seem to be sufficient to reliably predict future success.

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Figure captions:

Figure 1: Flowchart of the data collection.

Figure 2: Visual representation of the prediction equation in the U17 category (full model).

Figure 3: Visual representation of the prediction equation in the U19 category (full model).

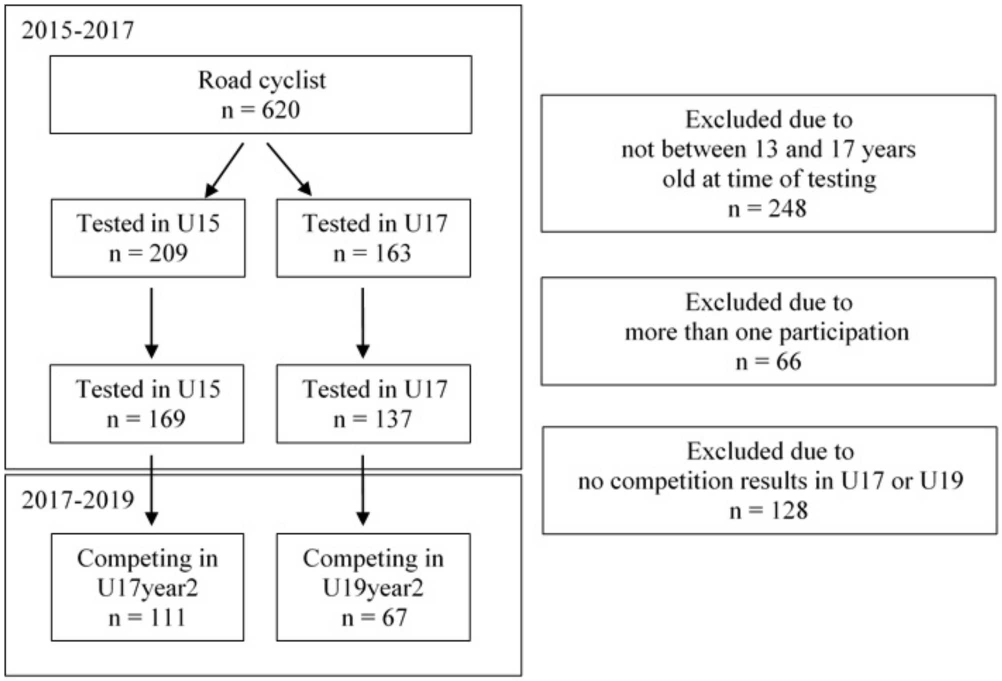

Figure 1: Flowchart of the data collection.

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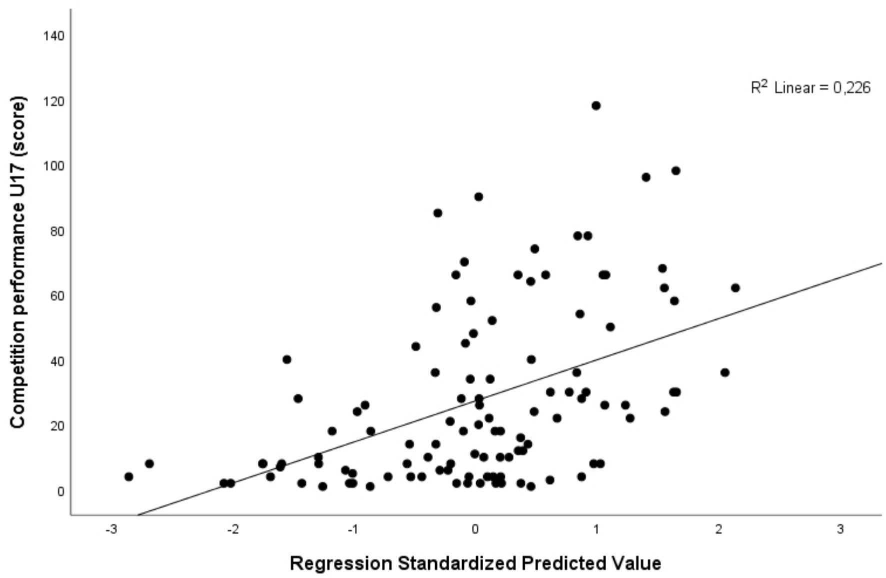

Figure 2: Visual representation of the prediction equation in the U17 category (full model).

570x336mm (38 x 38 DPI)

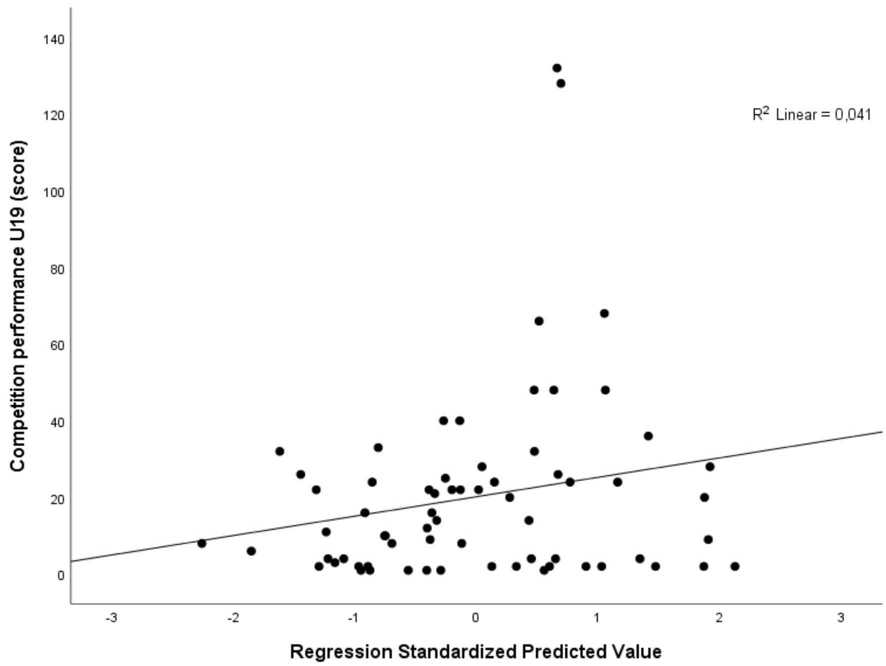

Figure 3: Visual representation of the prediction equation in the U19 category (full model).

570x390mm (38 x 38 DPI)

Table 1: Scores awarded to performance results at provincial and national championships.

Placement	Scores Provincial Championships	Scores National Championships
1	20	40
2	18	36
3	16	32
4	14	28
5	12	24
>5	10	20
>10	8	16
>15	6	12
>20	4	8
>30	2	4
DNF/DNS*	1	2

*DNF = did not finish; DNS = did not start

Table 2: Average performance on the anthropometric, physical, motor coordination, and cycling-specific tests (± SD) of the road cyclists.

	U15 (N=111)		**U17 (N=67)**	
	Mean	**SD**	**Mean**	**SD**
Age (years)	13.7	0.6	15.5	0.6
Competitive performance (score)	27.4	26.6	20.2	25.1
APHV (years)	13.7	0.7	13.9	0.5
Body height (cm)	164.5	9.8	175.13	7.2
Body weight (kg)	50.5	9.6	60.54	8.1
Motor Coordination (z-score)	-0.02	0.79	0.00	0.76
Moving sideways (N)	62	8	65	9
Jumping sideways (N)	87	11	92	10
Balance beam (N)	54	11	54	11
Physical Performance (z-score)	0.00	0.66	-0.01	0.64
Planking (sec)	123	50	140	45
Standing broad jump (cm)	183	21	194	20
Sit and reach (cm)	24.4	7.6	25.9	7.2
Endurance Shuttle Run (min)	9.6	1.7	11.0	1.5
30m Sprint (sec)	4.983	0.299	4.784	0.266
Cycling Specific (z-score)	-0.01	0.73	0.01	0.79
Shuttle bike (sec)	12.564	1.476	12.290	1.444
Maximal cadence (N)	200	13	210	12

Birth quarters (N)	**Q1**	**Q2**	**Q3**	**Q4**
U15	36 (32%)	39 (35%)	22 (20%)	14 (13%)
U17	14 (21%)	19 (28%)	17 (25%)	17 (25%)

Maturity status (N)	**Early**	**Average**	**Late**
U15	13 (12%)	90 (81%)	8 (7%)
U17	0 (0%)	65 (97%)	2 (3%)

Table 3: Results of the standardised hierarchical regression analyses for the U15 group.

Variable	B		SE	β	R²	F		ΔR²	ΔF²	
Stage 1					**0.078**	**4.540**	*	**0.078**	**4.540**	*
Constant	165.907	***	46.066							
APHV	-9.836	**	3.309	-0.275						
Relative age effect	-5.787		9.483	-0.056						
Stage 2					**0.205**	**9.204**	***	**0.128**	**17.172**	***
Constant	172.118	***	42.988							
APHV	-10.111	**	3.087	-0.283						
Relative age effect	-9.513		8.889	-0.093						
Motor coordination	12.146	***	2.931	0.359						
Stage 3					**0.215**	**7.250**	***	**0.010**	**1.310**	
Constant	158.405	**	44.566							
APHV	-9.071	**	3.214	-0.254						
Relative age effect	-10.518		8.920	-0.103						
Motor coordination	10.006	**	3.473	0.296						
Physical performance	4.906		4.286	0.121						
Stage 4					**0.226**	**6.131**	***	**0.011**	**1.512**	
Constant	152.255	**	44.739							
APHV	-8.587	**	3.230	-0.240						
Relative age effect	-11.305		8.921	-0.110						
Motor coordination	9.006	*	3.559	0.266						
Physical performance	3.500		4.426	0.087						
Cycling-specific performance	4.463		3.629	0.122						

Note: *p<0.05; **p<0.01; ***p<0.001

Table 4: Results of the standardised hierarchical regression analyses for the U17 group.

Variable	B	SE	β	R^2	F	ΔR^2	ΔF^2
Stage 1				0.013	0.421	0.013	0.421
Constant	-52.460	83.750					
Maturity ratio	5.154	6.086	0.108				
Relative age effect	1.817	11.162	0.021				
Stage 2				0.019	0.416	0.006	0.415
Constant	-58.071	84.585					
Maturity ratio	5.569	6.148	0.116				
Relative age effect	1.489	11.225	0.017				
Motor coordination	2.664	4.133	0.081				
Stage 3				0.021	0.336	0.002	0.113
Constant	-67.421	89.597					
Maturity ratio	6.235	6.499	0.130				
Relative age effect	1.692	11.321	0.019				
Motor coordination	1.822	4.856	0.055				
Physical performance	2.058	6.111	0.052				
Stage 4				0.041	0.521	0.020	1.257
Constant	126.310	77.078					
Maturity ratio	-97.634	69.468	-0.182				
Relative age effect	6.116	11.125	0.070				
Motor coordination	4.417	5.339	0.134				
Physical performance	3.574	6.053	0.091				
Cycling-specific performance	-5.682	4.878	-0.178				

Note: *p<0.05; **p<0.01; ***p<0.001