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**Title R1:** Predicting the sprint performance of adolescent track-cyclists using the three-min all-out test

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**ABSTRACT**

This study aimed to predict 500 m time-trial (TT) and 2,000 m pursuit speed of adolescent cyclists (age range = 13-15 years) using mechanical parameters derived from a Critical Power (CP) test and anthropometric variables. Ten well-trained, competitive cyclists were assessed for body composition, body mass, stature and Frontal Surface Area (FSA), as well as completing the CP test. The personal best speed (km·h-1) of each rider during competition in 500 m TT and 2,000 m pursuit races was predicted based on the CP test data and anthropometric profiles using multiple regression analysis. A combination of the CP·FSA-1 and internal (predicted) to external work ratio performed by the cyclists (Wint : Wext) predicted 500 m TT speed (*R2* = 0.97; SEE = 0.82, *P* = < 0.001), whilst a combination of MP·FSA-1 (mean power) and body fat percentage predicted 2,000 m pursuit speed (*R2* = 0.90; SEE = 1.5, *P* < 0.001). Between 90 - 97% of the variance in the sprint performance of adolescent cyclists can be explained by mechanical and anthropometric parameters, derived from a single visit to the laboratory. The tests and equations provided can be adopted by coaches to predict performance and set appropriate training intensities.

**INTRODUCTION**

A concept known as the ‘critical power’ (CP) demarcates the boundary between heavy and severe exercise domains and can be used to estimate anaerobic energy contributions and other parameters of physiological function, during exhaustive exercise protocols (8). More specifically, the CP represents the highest sustainable power output that does not cause a progressive disturbance of metabolic homeostasis, with exercise above this intensity leading to continual increases in pulmonary oxygen uptake (O2) and blood lactate [Bla], alongside proportional declines in muscle phosphocreatine [PCr] stores (17). As such, the CP provides a boundary that relates to both metabolic and respiratory control processes in the exercising human and can be used to assess physical fitness, set training intensities and predict performance in sports such as cycling (17). For example, the CP derived from the three-minute, all-out test has recently been shown to predict 16 km time-trial performance among adult cyclists (4). However, the ability of this test to predict the performance of adolescent time-trial cyclists competing in short (< 2,000 m) events has not yet been investigated.

The CP is typically measured over several days and bouts of constant load exercise, which results in a characteristic hyperbolic relationship between power output and time to exhaustion (30). A linear plot of power output against the inverse of time (1/time) reveals both the CP (*y*-intercept) and the so-called ‘anaerobic work capacity’ (W'), which is determined from the slope of the regression line. This relationship is described by the following equation (9,30);

P = CP + W'/time (1)

Since the W' is the maximal amount of work that can be achieved above the CP, it follows that the point at which the complete exhaustion of W', the CP would be highest sustainable power output (i.e. CP = P when W' = 0). On this basis, it has been shown that W' can be completely utilized in a single all-out, three-min exercise bout, thus permitting the calculation of the CP and an equivalent W' value. This is referred to as the ‘work end power’ (WEP), which represents the work done above the mean end power. This can be reliably determined from a single-visit, three-min, all-out test on a cycle ergometer (9,30). One could re-arrange equation 1 to estimate the performance time of an athlete (time = W'/(P-CP)) or combine these parameters with other mechanical variables that can be obtained from the three-min, all-out test.

Other useful performance parameters that can be measured during the three-min CP test include peak power (PP) and the total mean power (MP). In addition, the total mechanical power during exercise (i.e. recorded via a cycle ergometer) may be divided into two components; internal (Wint) or external (Wext) power. In cycling, the Wint is described as the work required to accelerate the lower limbs against gravitational and inertial forces with respect to the body’s center of mass, whilst the Wext is equivalent to the work performed against external resistance (25). Theoretically, if one were to reduce the amount of Wint required for a given exercise bout, then more energy would remain to contribute to Wext,thus supporting forward propulsion, which is important for sprint cycling events. The subsequent generation of greater external work (and power) for the same metabolic cost would improve gross efficiency (28). Indeed, in short sprint events where high power outputs are observed, the race result would be sensitive to the biomechanical efficiency of the rider.

Track cycling competitions feature sprint events, such as the 500 m time trial (TT) and the 2,000 m individual pursuit, which are approximately of 35-s and 3-min duration, respectively. Both adult (> 18 years) and junior (child/adolescents < 18 years) cyclists compete in these events at national and international levels. Among adult sprint cyclists, the ability to generate both mean and peak total mechanical power is important for performance (7). Indeed, peak mechanical power outputs of approximately 1900 W or 22 W· kg-1 have been reported during sprint races of a similar distance (7,12). The capacity to generate power outputs of such magnitudes during exhaustive exercise bouts between 30-s and 3-min, elicits anaerobic energy contributions of between 70% and 30%, respectively (13,24). However, the ability of adolescent athletes to generate high mechanical power is distinctly less than that of adults and appears to be related to a smaller limb lengths, reduced muscle mass, lower composition and recruitment of type II muscle fibers and reduced glycolytic enzyme activity (26,29). Given that lean leg thigh volume explains 70% – 80% of the variance in maximal power among adults (20-21), the smaller lean muscle mass of adolescent riders is likely to hinder their power production during sprint events. Furthermore, the reduced anaerobic energy release of adolescent cyclists is likely to limit their performance in short sprint events that require substantial contributions from non-oxidative energy pathways.

Given the morphological and metabolic differences between adults and children/adolescents, it is plausible that they do not share the same predictors of track cycling performance. While the time-efficient and valid nature of the CP test is apparent, there has been no investigation of its relationship to track cycling performance in well-trained adolescent athletes. Taken collectively, the range of parameters that can be measured during the single visit make this test attractive to cycling practitioners and athletes who often have limited time with which to perform periodic assessments. The information derived from this test could be used by coaches to predict performance and set appropriate training intensities. Accordingly, based on the various mechanical parameters obtained from the single-visit, three-min CP test and anthropometrical data, the aim of this study was to identify the combination of factors that best predicted the personal best track speeds of well-trained, adolescent track cyclists. Given the duration of the 2,000 m time-trial, we hypothesized that the CP, determined from the three-minute, all-out test, would predict performance in this event. Both peak power and WEP were expected to explain the majority of variance in 500 m time-trials. However, because of the importance of other factors such as mean power (1,12) and the anthropometrical profile of cyclists (11,22-23), it was not known which combination of variables would best predict the performance of adolescent track cyclists.

**METHODS**

**Experimental Approach to the Problem**

During one single visit to the laboratory, various mechanical performance variables on the cycle ergometer, as well as anthropometric parameters were measured, with the aim of predicting sprint cycling performance. It was hypothesized that a combination of the mechanical variables measured during the three-min all-out test (i.e. CP, WEP, PP, Wint, Wext) would explain the variance in 500 and 2,000 m TT performance, based on their known associations with energy system utilization. Given the aforementioned importance of body size and shape to cycling performance, as well as its interactions with other mechanical variables, body mass, body fat and FSA were also hypothesized to contribute to a predictive model of sprint cycling performance. Using stepwise linear regression, the variables measured in the laboratory visit were used to predict the personal best 500 m TT and 2,000 m pursuit speeds of each participant, performed at the junior state titles less than two weeks before the laboratory assessment. Prediction equations were subsequently developed based on the variable, or combination of variables, that best predicted performance.

**Participants**

Ten competitive adolescent cyclists, six male (age = 14.9 ± 0.1 years; stature = 176.6 ± 9.4 cm; body mass = 66.1 ± 10.9 kg) and four female (age = 14.5 ± 0.6 years; stature = 166.8 ± 2.9 cm; body mass = 53.8 ± 5.9 kg), consented to take part in this study. Informed consent was also obtained from the parent/guardians of the participants. Ethical approval was granted for this study from the University’s Human Ethics Committee. The cyclists were all members of a semi-professional road cycling team, taking part in approximately 15-25 hours of conditioning per week and had been training for and competing in both weekly road and track cycling races for the previous 3.3 ± 0.4 years. The participants were instructed to rest on the day prior to the test, be sufficiently hydrated, and consume no caffeine on the day or any food in the two hours before the testing session.

**PROCEDURES**

**Anthropometry**

Each participant visited the laboratory once, at the same time of day. During their visit, participants were profiled by a trained anthropometrist (Level 1, ISAK). The assessment included skin-fold measurements of the; biceps, triceps, subscapular, iliac crest, supraspinale, abdominal, front thigh and medial calf (Harpenden callipers, British Indicators, UK). Each site was measured three times from which the median value was recorded. Subsequent estimations of body fat percentage (BF%) were based on the equation of Withers et al (32). Whilst the equation of Withers was intended for use with females, data from our laboratory demonstrate agreement with other non-gender specific equations. The participants’ lean body mass (LBM) was calculated using the total body mass and body fat estimation. The intra-tester reliability for the sum of six skin-folds was 2.0% (Coefficient of Variation; CV), determined from two trials performed on different days. The participant’s frontal surface area (FSA; m2) was predicted using the equation of McLean (22) ((0.00215 BM) + (0.18964 S) - 0.07961)), where BM = body mass (kg) and S = stature (cm). This equation assumes a seated posture with hands on the drop-handlebars of the bicycle. The performance data were later normalized to both body mass and frontal surface area (23).

**Three-min all-out Critical Power test**

Following their body measurements, the participants took part in a three-min, all-out test on a mechanically-braked cycle ergometer (Lode Excalibur Sport, Groningen, Netherlands), which was adjusted to the participant based on their personal preference. The participants firstly performed a warm-up at 50 W of external power for 5-min, followed by 5-min of seated rest (no pedalling) on the bike. In the next stage, the participant cycled in isokinetic mode (unloaded) on the ergometer for 2-min and 50-s at a cadence of 90 rpm, followed by a 10-s period of 110 rpm. A countdown was given in the last 5-s of the isokinetic phase to lead in to the three-min all-out test, which was performed in linear mode. To perform in linear mode, the participant’s linear factor is typically determined such that the mechanical power output midway between GET and O2max is achieved upon reaching their preferred cadence (30) (linear factor = power (W)/cadence (RPM)2). Since the current study aimed to identify whether performance could be predicted based on the combination of CP and anthropometrical tests in a single-visit, the linear factor was optimized at a mean of 0.043 and 0.037 for male and female participants, respectively. This was based on a database of information previously collected in our laboratory. The participants were verbally encouraged throughout the test by the researchers. The three-min CP trial was followed by 5-min recovery at 50 W. The peak power (PP) was determined as the highest external power maintained over a 1-s period and the mean power was determined as the average power maintained over the total 3-min period. The end-power, hereafter referred to as the CP, was determined as the average external power sustained during the final 30-s of the test. The work above end power (WEP) was determined as the amount of external work (kJ) performed above the CP during the three-min test. Each variable was expressed in absolute terms and normalized to both body mass and FSA.

To verify the intensity of the exercise bout, the peak heart rate was obtained from a telemetric heart rate monitor (Polar Electro Oy, Kempele, Finland), which was fitted to the participant prior to the warm-up period. In addition, at the beginning (pre-warm-up) and 1-min after the end of the CP test, a capillary blood sample was collected from the finger to measure the change in blood lactate concentration ([Bla] mmol·l-1) (Lactate Pro; Arkray KDK Corp., Kyoto, Japan).

**Internal power estimation**

The sum of both mechanical internal (Wint) and external work (Wext) components was viewed to be equal to the total work (Wtot) performed (6). According to the equation of Minetti et al. (25),internal power (Pint) can be estimated from body mass and pedal frequency (Hz) as follows; Pint = = 0.153 BM cadence3; where BM is body mass (kg) and cadence is measured in Hz. The amount of internal work performed (Wint) can subsequently be deduced (*p* x *t*); where *p* = power (W) and *t* = time (s). The ratio of Wint to Wext (Wint : Wext) was calculated, with the view that a lower value would reflect a more efficient cyclist. That is; more energy would be available to contribute to external mechanical power, thus enhancing gross efficiency (external power/metabolic power).

**500 m TT and 2,000 m pursuit speed records**

The personal best 500 m TT speed (km·h-1) and 2,000 m pursuit speed (km·h-1) was taken from the official records of Cycling New South Wales (NSW), performed at the junior state titles less than two weeks before the laboratory assessments (http://www.nsw.cycling.org.au). All of the riders performed the races on their own bikes, on the same 250 m wooden, indoor velodrome track, on the same day.

**STATISTICAL ANALYSES**

The bivariate relationships between either 500 m TT or 2,000 m pursuit speeds (km·h-1) and the variables calculated during the three-min test (PP, PP·kg-1, PP·FSA-1,MP, MP·kg-1,MP·FSA-1, CP, CP·kg-1, CP·FSA-1, WEP, Wint, Wext, Wtot and Wint : Wext) and the anthropometrical data (BM, LBM, FSA and BF%), were determined using Pearson’s correlation coefficient (*r*). The strength of the correlation was assessed according to the recommendation of Hopkins et al. (15), where 0.1, 0.3, 0.5, 0.7 and 0.9 indicated small, moderate, large, very large and extremely large relationships. Significance was set at *P* < 0.05 for the correlational analysis. After establishing normal distribution of the residuals, two stepwise linear regression analyses were performed with either mean speed from the 500 m TT or the 2,000 m pursuit as the dependent variables. The collective contribution of the same predictor variables was considered; however, a number of variables were removed following checks for collinearity, using a tolerance of < 0.10 (variance inflation factor). The significance of *F* for entry into the model set at 0.05 and removal, 0.10. The adjusted coefficient of determination (*R2*) and the associated standard error of the estimate (SEE; km·h-1) were calculated to show the degree of variation in either 500 m TT or 2,000 pursuit speed that could be explained by the predictor variables. Data are presented as means and standard deviations (SD) throughout. Statistical tests were carried out on SPSS version 19.

**RESULTS**

Table 1 shows the descriptive data of the adolescent cyclists during the three-min, all-out CP test, anthropometry assessment and performance on the track. The participants’ peak HR was 188 ± 4 bpm and was 178 ± 4 bpm at the end of the test. The [Bla] was 2.6 ± 0.8 mmol·l-1 at the start of the warm-up and 13.5 ± 1.8 mmol·l-1 one-min after the CP test. Figure 1 shows the power profile of a representative male participant during the three-min, all-out test.

**\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*Insert Table 1 here\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\***

**\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*Insert Figure 1 here\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\***

The only variable not correlate with TTperformance was PP·kg-1 (Table 2). Of all the variables measured in the three-min CP test, the strongest and most consistent correlates of both 500 m TT and 2,000 m pursuit speed were; MP, CP, MP·FSA-1 and CP·FSA-1 (Table 2).Peak power, PP·kg-1 and PP·FSA-1 were generally less well correlated to 500 m TT and 2,000 m pursuit speed (Table 2). While the WEP was correlated to 2,000 m pursuit speed, it demonstrated a weaker, yet ‘large’ correlation to 500 m TT speed.

**\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*Insert Table 2 here\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\***

Lean body mass was the strongest correlate of both 500 m TT and 2,000 m pursuit speed (*r* = 0.86 and *r* = 0.79, respectively). There was a stronger inverse relationship between BF% and 2,000 m pursuit speed (*r* = -0.90) compared to 500 m TT speed (*r* = -0.73).

As shown in Table 3, both CP·FSA-1 and Wint : Wext provided a significant contribution to the linear regression model that explained 97% of the variance in 500 m TT speed (*R2* = 0.97; SEE = 0.82 km·h-1, *P* = < 0.001), yielding the equation;

500 m TT speed = 27.389 + (0.023 × CP·FSA-1) + (7.714 × Wint : Wext)  **(2)**

A different group of variables, MP·FSA-1 and BF% explained 90% of the variance in 2,000 m pursuit speed (*R2* = 0.90; SEE = 1.5 km·h-1, *P* < 0.001), yielding the equation;

2,000 m pursuit speed = 31.903 - (0.345 × BF%) + (0.019 × MP·FSA-1) **(3)**

**\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*Insert Table 3 here\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\***

**DISCUSSION**

As anticipated, the majority of variables measured during the three-min, all-out critical power test were significantly related to the performance of the riders in both the 500 m TT and 2,000 m pursuit event. However, there were consistently stronger relationships between the shorter 500 m TT speed and the absolute parameters of the CP test (i.e. MP and CP). This was unexpected given the assumed predominant contribution of oxidative energy pathways to support performance during the CP test, as well as the known association of the CP with endurance performance (3,17). Furthermore, the CP test duration (3-min) is closely related to the average 2,000 m pursuit time of the current riders (~ 2.5-min), which, much like the CP test, is optimally performed using an ‘all-out’ pacing strategy (10). Such findings could be attributed to the validity of the three-min, all-out test, the use of which has been questioned among untrained adolescent participants (2). However, the validity of the three-min, all-out test has not yet been investigated among well-trained and appropriately familiarized adolescent track cyclists, performing at their preferred cadence. It would be useful for future research to evaluate this aspect.

A potential explanation for such findings might also relate to the limited ability of adolescents to utilise energy from anaerobic pathways, inducing a relatively high reliance on oxidative energy pathways during all-out exercise (9,27). Factors such as fast oxidative enzyme rate have been proposed to prompt an earlier reliance on aerobic metabolism during all-out cycling exercise among children of a similar age (age = 14.6 years) (5). In accordance with this theory, there was a poorer relationship between the absolute and relative variants of PP and performance speeds in both events (Table 2). It was anticipated that characteristics, such as PP parameters, relying predominantly on anaerobic energy production, would relate more strongly to sprint cycling performance. These weaker relationships were observed despite the current participants’ values (743 ± 149 W) being markedly higher than those reported among recreationally active adolescents of the same age (PP = 492 - 533 W) (2,5), thus reflecting the training status of the current sample. Furthermore, the WEP of the riders demonstrated a stronger relationship with the longer 2,000 m pursuit event (*r* = 0.88) compared to the 500 m TT (*r* = 0.63). Whilst the WEP has a logical relationship with the 2,000 m pursuit speed (7), its poorer relationship with 500 m TT speed was also unexpected owing to the predominant reliance on the ATP-PC system and anaerobic glycolysis during short (~36 s), all-out periods of exercise (13,16,24). Given the brief duration of the 500 m TT events measured in the current study (37.0 ± 3.3 s), it is also likely that the subjects ability to fully utilise their WEP was limited, which might have also weakened the relationship between WEP and TT speed. Collectively, our findings indicate that sprint cycling performance of well-trained adolescents is predominantly explained by factors that reflect aerobically-supported performance qualities of the rider, even in short, all-out events such as the 500 m TT. Of course, the training history of the current sample as endurance-based road cyclists might have also biased aerobic development, further hindering their capacity to produce power via non-oxidative energy pathways.

Whilst we have hypothesized that our findings might reflect the immature physiological capacities of the adolescent riders, it has also been shown that PP and PP·kg-1, obtained during a torque-velocity test, poorly relate to 200 m TT performance among adult cyclists (11). Furthermore, reports have suggested that international adult cyclists produce a lower peak power, yet high mean power, compared to domestic cyclists during competitive sprint events (12). Therefore, there is some evidence to suggest that peak power provides a relatively smaller contribution to sprint cycling performance, independent of age. Logically, a cyclist with the ability to achieve a higher peak power over a short duration is likely to utilize their finite anaerobic energy capacity (i.e. WEP) at a faster rate. Such a scenario would leave less anaerobic energy available to support power production and result in the rider reaching their CP earlier. This reasoning might explain why absolute or relative PP variants were not among the strongest predictors of performance as there would be less use for this during competition.

In line with previous reports in both adult and junior track cyclists (11,23), it is also likely that the poorer relationship of PP relates to the greater body mass and, thus, larger FSA that accompanied the higher PP of the current cyclists. We found that normalizing the PP (as well as MP and CP) of the riders to FSA, rather than body mass, improved their predictions of performance (Table 2). Such findings reaffirm the substantial metabolic cost attributed to overcoming air resistance in cycling (1,11,19), highlighting the importance of balancing gains in lean, propulsive muscle mass with an aerodynamic (smaller) frontal profile. Therefore, our results suggest that a high CP or MP, accompanied by a small frontal profile is of the greatest importance for adolescent sprint cyclists. Indeed, both CP·FSA-1 and MP·FSA-1 were the strongest contributors to the prediction of either 500 m TT or 2,000 m pursuit speed, respectively (Table 3). Interestingly, BF% also contributed to the prediction of 2,000 m pursuit speed, which would support a reduction in frontal profile whilst increasing relative muscle mass and, therefore, mean external power production. Cycling practitioners should aim to prioritize training methods that enhance each of the above qualities.

To the best of our knowledge, this is the first time Wint has been investigated as a potential predictor of track cycling performance. In cycling, the predicted Wint is defined as the work done on the limbs to overcome gravitational and inertial forces, relative to the COM (25). In contrast, Wext is the work done to overcome air resistance, rolling resistance, gravity (where terrain is not flat) and to change velocity. The sum of these loads determines the force necessarily applied to the drive-train i.e. pedals. By definition, energy expenditure attributed to Wext results in forward propulsion, whilst energy expended to perform Wint does not; however, this remains a matter of debate (18). With this understanding, cyclists that perform a greater amount of internal work for a given external workload are likely to be less efficient in a race scenario, since a greater proportion of the work performed will be internally dissipated for the same ATP consumption (14,25).

The Wint:Wext provided a significant contribution to the prediction of 500 m TT speed (Table 3) among well-trained adolescent cyclists, which does not necessarily support the hypothetical benefit of minimising Wint for a given Wext. The higher Wint:Wext values frequently occurred in conjunction with higher Wint values, which supports the assertion that reducing Wint would not permit a greater amount of energy to be used externally (Wext). Indeed, our findings lend greater support to the assumption that Wint and Wext are not exclusive energy sources (18) and that improvements in Wint mightfacilitate greater external mechanical power. The manipulation of Wint can be achieved by altering cadence (14), bicycle/rider geometry and the use of elliptical chainrings, as they are the most readily controlled determinants (18). Further research is needed to confirm how these variables may be manipulated to optimise Wint:Wext, and the subsequent effect on performance. This is particularly pertinent to adolescents who are likely to experience increases in body size and co-ordination whilst physically maturing (27). Indeed, it is important to investigate the potential differences between adults and adolescents in the Wint:Wext and its relationship to performance in thesepopulations.

There are some potential limitations to the study owing to its applied nature, such as size of the current sample (*n* = 10) and the mixed cohort of male and female cyclists. However, all of the riders were part of the same racing team, possessed a similar degree of track and laboratory experience and, collectively, represented a well-trained, competitive adolescent group of Australian cyclists. Therefore, this group is typical of that serviced by cycling coaches and applied physiologists. Furthermore, based on the mean ± SD performance data of the riders and the small SEE associated with each prediction equation, we view the current sample to be a homogenous group of junior cyclists. The proportion of male and female participants of the current sample also closely replicates that of previous studies investigating the three-min CP test among non-elite groups (2,31),thus permitting cross-comparisons.

**PRACTICAL APPLICATIONS**

The current testing procedures are non-invasive and time-effective, which is useful for track cycling practitioners. We suggest that the CP test is particularly relevant for the assessment of sprint track cyclists owing to the ‘all-out’ nature of the protocol that appropriately mimics the optimal pacing strategy of short, sprint races (10). As well as reaffirming the importance of MP, CP and their interaction with FSA for sprint cycling performance, for the first time, the ratio between internal and external work performed (Wint : Wext) has been shown to strongly predict 500 m TT speed. The equations provided herein can be adopted by coaches to predict performance and set appropriate training intensities. It is important that potential users of the prediction models consider selecting participants with similar physical (stature, body mass, age) characteristics and training backgrounds in order to ensure their validity.

The capacity of an adolescent cyclist to produce a high CP or MP, accompanied by a small frontal profile and lower BF% is of the greatest importance sprint performance, denoted by the contributions CP·FSA-1 and MP·FSA-1 to the predictive models. Therefore, training methods that reduce frontal profile, whilst increasing relative muscle mass and mean external power production should be prioritized by cycling practitioners.

Whilst it is certainly important for adolescent sprint cyclists to harness maximal energy from all available sources during a race, it would appear that this is optimized among riders with a higher CP and MP, particularly when normalized to FSA. Our findings have revealed that between 90 - 97% of the variance in the sprint performance of adolescent track cyclists can be explained by simple mechanical and anthropometric parameters, derived from a single visit to the laboratory. Future research should aim to identify effective methods of optimizing Wint : Wext.

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**Table 1.** Critical power test, anthropometry and track performance data of the adolescent cyclists (*n* = 10).

|  |  |  |  |
| --- | --- | --- | --- |
|  | Mean | ± | SD |
| **Critical Power test** |  |  |  |
| Peak power (W) | 743.9 | ± | 149.6 |
| Mean Power (W) | 382.5 | ± | 103.0 |
| Critical Power (W) | 321.2 | ± | 90.4 |
| WEP (kJ) | 12.0 | ± | 3.5 |
| Wext (kJ) | 72.6 | ± | 19.2 |
| Wint (kJ) | 19.0 | ± | 11.7 |
| Wtot (kJ) | 91.6 | ± | 30.6 |
| Wint : Wext | 0.2 | ± | 0.1 |
| PP·kg-1 (W·kg-1) | 12.2 | ± | 0.9 |
| MP·kg-1 (W·kg-1) | 6.2 | ± | 0.8 |
| CP·kg-1 (W·kg-1) | 5.2 | ± | 0.8 |
| PP·FSA-1 (W·m-2) | 1959.2 | ± | 198.5 |
| MP·FSA-1 (W·m-2) | 1001.9 | ± | 178.9 |
| CP·FSA-1 (W·m-2) | 840.7 | ± | 160.8 |
| **Anthropometry** |  |  |  |
| Body mass (kg) | 61.2 | ± | 10.9 |
| Body fat (%) | 11.2 | ± | 4.2 |
| Lean body mass (kg) | 54.5 | ± | 11.1 |
| FSA (m2) | 0.4 | ± | 0.0 |
| **Track Performance** |  |  |  |
| 500 m TT (km·h-1) | 49.0 | ± | 4.4 |
| 2,000 m TT (km·h-1) | 46.7 | ± | 4.8 |
| 500 m TT (s) | 37.0 | ± | 3.3 |
| 2,000 m TT (s) | 155.6 | ± | 16.3 |

**Note:** WEP = work done above end test power; Wext = external work; Wint = internal work; Wtot = total work; PP = peak power; MP = mean power; CP = critical power; FSA = frontal surface area; TT = time trial.

**Table 2.** The relationship between the critical power test, anthropometry and track speed data (500 m TT and 2,000 m pursuit) of the adolescent cyclists (*n* = 10).

|  |  |  |
| --- | --- | --- |
|  | **Pearson correlation (*r*-value)** | |
|  | **500 m TT speed (km·h-1)** | **2,000 m pursuit speed (km·h-1)** |
| **Critical Power test** |  |  |
| Peak power (W) | 0.79\* | 0.78\* |
| Mean power (W) | 0.95\* | 0.90\* |
| Critical power (W) | 0.95\* | 0.90\* |
| WEP (W) | 0.63\* | 0.88\* |
| Wext (kJ) | 0.95\* | 0.90\* |
| Wint (kJ) | 0.88\* | 0.82\* |
| Wtot (kJ) | 0.93\* | 0.87\* |
| Wint : Wext | 0.95\* | 0.88\* |
| PP·kg-1 (W·kg-1) | 0.24 | 0.42 |
| MP·kg-1 (W·kg-1) | 0.89\* | 0.93\* |
| CP·kg-1 (W·kg-1) | 0.91\* | 0.92\* |
| PP·FSA-1 (W·m-2) | 0.75\* | 0.77\* |
| MP·FSA-1 (W·m-2) | 0.96\* | 0.94\* |
| CP·FSA-1 (W·m-2) | 0.96\* | 0.92\* |
| **Anthropometry** |  |  |
| Body mass (kg) | 0.78\* | 0.68\* |
| Body fat (%) | -0.73\* | -0.90\* |
| Lean body mass (kg) | 0.86\* | 0.79\* |
| FSA (m2) | 0.78\* | 0.72\* |

**Note:** \* = significant (*P* < 0.05).

**Table 3.** Standardized beta coefficients and significance values for the prediction of 500 m TT and 2,000 m pursuit speed among the adolescent cyclists (*n* = 10).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Beta coefficients (***ß***)** | ***t*-value** | **Significance**  **(*P*-value)** |
| **500 m TT speed (km·h-1)** |  |  |  |
| CP·FSA-1 | 0.023 | 7.213 | 0.001 |
| Wint : Wext | 7.714 | 2.225 | 0.031 |
| **2,000 m pursuit speed (km·h-1)** | |  |  |
| MP·FSA-1 | 0.019 | 3.981 | 0.005 |
| Body fat (%) | -0.345 | -2.150 | 0.010 |

**Note:**Adjusted R2 = 0.0.97 for 500 m TT model and 0.90 for 2,000 m pursuit model.

**Figure 1.** The critical power (CP = 333 W) and work end power (WEP = 12.3 kJ) estimated from the power profile of a representative male participant during the three-min, all-out test. The dashed line represents the CP, with all work done above this line equal to the WEP.