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ABSTRACT

With the draft-legal rule recently introduced to junior triathlon competition, it has become difficult to assess cycling performance through race results. Therefore, this study assessed the cycling power profile characteristics of national level junior triathletes to assist with physical assessment and program design. Thirteen male (17.0 ± 1.0 yr) and eleven female (17.2 ± 1.3 yr) national level junior triathletes completed a cycling power profile that consisted of maximal intervals that lasted 6, 15, 30, 60, 240 and 600 seconds in duration. Each power profile was completed on a LeMond ergometer using the subject's own bicycle, with power output and cadence recorded for all intervals. Mean power output values for males (783 ± 134, 768 ± 118, 609 ± 101, 470 ± 65, 323 ± 38, 287 ± 34 W) were significantly ($P<0.05$) higher than females (554 ± 92, 510 ± 89, 437 ± 75, 349 ± 56, 248 ± 39, 214 ± 37 W) across all intervals, respectively. Peak power output values for males across the 6 and 15 second intervals (1011 ± 178 and 962 ± 170 W) were also significantly higher than for females (674 ± 116 and 624 ± 114 W), respectively ($P<0.05$). Developing junior triathletes should aim to increase their capacity across the power profile above the mean values listed. Athletes should further aim to have power outputs equal to that of the best performers and beyond to ensure that they can meet the demands of any competition situation.

Keywords: triathlon, youth, draft-legal, coaching, testing

INTRODUCTION

Triathlon is a multidisciplinary sport encompassing the sequential completion of swimming, cycling and running stages. In elite senior and junior competition, racing is classed as ‘draft-legal’, permitting athletes to closely follow one another (i.e. drafting) during the cycling stage to reduce drag forces (2, 11). While drafting may also be beneficial during the swimming and running stages, it has particular importance during the cycling stage due to the increased wind resistance creating greater drag at high speeds (12). Specifically, drafting behind small (i.e. 1-4 riders) and large (i.e. 8 or more riders) groups of cyclists has been shown to reduce the oxygen consumption requirement to sustain a given speed by as much as 27 ± 7% and 39 ± 6%, respectively (5). Hence, drafting allows individual competitors to alternate between higher intensity efforts whilst leading the group or making a breakaway manoeuvre, with interspersed lower intensity efforts when drafting to conserve energy. A study of male international Olympic distance triathlon competition revealed that 34 ± 14 high intensity efforts (>600 W) were performed during the cycling stage and 18% of total cycling time exceeded maximal aerobic power (3), highlighting the intermittent demands of the race. Hence, the tactical nature of drafting transforms the demands of the cycling stage into a high-intensity, intermittent activity.

Due to the tactical nature of the draft-legal format, the cycling performance of opponent triathletes during such competitions (i.e. their maximal performance over various durations) is difficult to assess. Performance in the swimming and running stages can be inferred from race times due to these stages more closely reflecting an individual time trial. However, in the cycling stage, athletes take advantage of the draft effect and ride together in groups, which means that they often finish with the same time (2). Also, many athletes will attempt to minimise power output during the cycling stage in order to conserve energy prior to the running stage (2, 8). Therefore, the optimal way to assess the maximal cycling capability of an athlete over various durations is through controlled laboratory testing.

Current laboratory-based research on cycling in triathlon has focused on assessing maximal aerobic capacity using incremental test protocols, with values as high as 74.3 ± 4.3 $mL\cdot kg^{-1}\cdot min^{-1}$ reported for elite senior competitors (6). Further, maximal aerobic power values of 385-389 W have been reported for senior elite triathletes (4, 6). The application of such data for draft-legal races is questionable considering that the high intensity, intermittent profile of the draft-legal format requires the assessment of a triathlete's complete aerobic and anaerobic capacities across various durations (3, 8). The cycling power profile is a reliable performance test incorporating maximal self-paced intervals of 6-600 seconds in duration (8) and it has recently been demonstrated to predict road cycling performance (8). It has also been recommended by the Australian Institute of Sport as a useful cycling test protocol for triathletes (13) and as a result it has been adopted by Australian state-level junior representative triathlon squads. As such, this test has become important for physical assessment and program design for these junior athletes, however, no normative data currently exists for this population, which would likely assist coaches and athletes with their interpretation of test results. Therefore the purpose of this study was to describe the laboratory power profile results of junior male and female triathletes competing at the national level.

METHODS

Experimental Approach to the problem

This descriptive study measured the power profile performance of national level junior triathletes in a standardised laboratory test consisting of six maximal self-paced intervals (6, 15, 30, 60, 240 and 600 s in duration) with periods of active recovery (174, 225, 330, 480 and

600 s in duration) as described previously (8). All cycling was completed on each subjects's own personal road bicycle that was attached to a LeMond Revolution cycle ergometer (LeMond Fitness Inc., Woodinville, Washington, USA). The LeMond Revolution takes the place of the rear wheel, using the bicycle's normal drivetrain to adjust resistance, which allows the use of equipment and bicycle geometry that is specific to each individual. Power output obtained from the LeMond Power Pilot (LeMond Fitness Inc., Woodinville, Washington, USA) has previously been validated against the SRM power meter with the level of agreement considered acceptable (7). Data was collected during training camps leading into competition when the athletes were close to their peak condition.

Subjects

Thirteen male (age: 17.0 ± 1.0 yr, stature: 176.6 ± 5.7 cm, body mass: 65.8 ± 7.1 kg, sum of 7 skinfolds: 49.4 ± 10.2 mm, body fat: 8.7 ± 1.7%) and eleven female (age: 17.2 ± 1.3 yr, stature: 166.8 ± 7.9 cm, body mass: 57.5 ± 7.7 kg, sum of 7 skinfolds: 76.5 ± 15.5 mm, body fat: 16.8 ± 3.9%) national level junior triathletes volunteered for the study. Inclusion criteria stipulated that subjects must be aged 16-19 years and currently competing in the Australian National Junior Triathlon Series over the sprint distance (i.e. 750 m swim, 20 km cycle, 5 km run). All subjects were familiar with riding on a cycle ergometer. All subjects and their guardians provided written informed consent prior to testing. An institutional ethics committee granted approval for the project (XXX H-2011-0350).

Procedures

An anthropometric profile was obtained from each participant consisting of stature (217 Stadiometer, Seca, Birmingham, United Kingdown), body mass (DS-530 electronic scales, Wedderburn, Sydney, Australia) and skinfold thickness at seven sites (Harpenden Calipers, Baty International, West Sussex, United Kingdom). The seven sites included bicep, tricep, subscapular, supraspinalae, abdominal, quadriceps and medial calf and these sites were summed to form the sum of 7 skinfolds (X_1). Body density was calculated with specific regression equations for male (14) and female (15) Australian athletes as per below (where X_2 = the sum of 6 skinfolds as above minus the bicep). Percent body fat was also estimated via the equation below (9).

$$\text{Male Body Density (14)} = 1.0988 - 0.0004(X_1)$$

$$\text{Female Body Density (15)} = 1.20953 - 0.08294(\text{Log}_{10}X_2)$$

$$\text{\% Body Fat (9)} = [4.95/\text{Body Density} - 4.5] \times 100$$

For 24 hours prior to the power profile, caffeine and high intensity exercise were not permitted and the athletes were instructed to consume their usual pre-race diet. The participants performed a standardised 10 min warm-up that consisted of riding between 100-200 W, as well as three six second intervals at 70, 80 and 90% of their perceived maximal intensity, respectively. The power profile test commenced two minutes later and all intervals began from a rolling start between 70-80 $r\cdot min^{-1}$. Verbal encouragement was provided during the intervals and participants were instructed to self select and adjust their gear ratio at any time to produce their best performance over each interval. The athletes were also instructed that the shorter intervals (6-15 s) were a maximal sprint while the longer intervals (30-600 seconds) required a self-selected pacing strategy to produce the maximal mean power. During active recovery, cyclists were instructed to pedal at a power output of <100 W. A 50 centimetre fan was placed 1 metre in front of the participant and provided a wind speed of 8 $m\cdot s^{-1}$ to simulate the convective cooling of outdoor conditions and tepid water (20-23°C) was ingested *ad libitum* as recommended (10).

Measures

Power output and cadence were recorded at a frequency of 1 Hz using a LeMond Power Pilot. The first second of data obtained in the 6 second intervals was not included in the data analysis as per previous research (8). Heart rate was recorded with a Garmin Forerunner 910XT heart rate monitor wrist watch and chest strap (Garmin Ltd., Canton of Schaffhausen, Switzerland). All data was downloaded post-test and arranged in Microsoft Excel (Microsoft Corporation^{TM}, Redmond, WA, USA) before further analysis. Power output data were also divided by the participant's body mass to calculate relative values.

Statistical Analyses

The data were examined for assumptions of normality using the Kolmogorov-Smirnov test and visually inspected through histograms and box plots. A two-way repeated measures ANOVA was used to determine the main effects of sex on power output, cadence and heart rate for each interval where it was measured. *Post hoc* comparisons with Bonferonni adjustment were used to identify any significant differences. All statistical analysis were conducted using SPSS software V22.0 (IBM Corporation, Somers, NY, USA). Power curves were plotted for each athlete and group means using Microsoft Excel's built-in power function ($R^2 > 0.94$ for all power curves) and a 'best perfomer' for both sexes was identified as the athlete who achieved the highest power output across all interval durations in the power profile itself and does not necessarility reflect the best performing triathlete in competition.

RESULTS

The descriptive statistics for mean power output measures of the group and the best performer across the power profile are presented in Table 1. All mean power outputs reported were significantly higher in males than females for both absolute and relative measures ($P<0.05$). Power curves of the group means and best performing male and female athlete across the power profile tests are presented in Figure 1.

Insert Table 1 Here

Insert Figure 1 Here

The descriptive statistics for peak power output measures of the group and the best performer across the 6 second and 15 second intervals are presented in Table 2. These peak power outputs were both significantly higher in males when compared to females for both absolute and relative measures ($P<0.05$).

Insert Table 2 Here

Mean and peak cadence measures of the group and best performer are presented in Table 3. Mean cadence measures were significantly higher in males when compared to females across the 15 and 30 second intervals ($P<0.05$). Peak cadence measures were significantly higher in males when compared to females across the 6 and 15 second intervals ($P<0.05$). There were no significant differences in cadences across any other interval ($P>0.05$).

Insert Table 3 Here

Mean heart rates across the 240 and 600 s intervals were 172 ± 8 beats·min^{-1} and 179 ± 6 beats·min^{-1} as well as 174 ± 7 beats·min^{-1} and 178 ± 5 beats·min^{-1} for males and females, respectively. No significant differences were observed between sexes for the heart rate measures ($P>0.05$).

DISCUSSION

This investigation has provided a novel insight into the cycling capacities of national level junior triathletes. This information is useful for a number of purposes including the preparation of athletes, monitoring changes in performance and talent identification. Such data provides a set of normative values for regular cycle-based testing, which can also help to identifiy specific strengths and weaknesses to benefit training prescription. Overall, the males outperformed the females, even when corrected for differences in body mass, although the gap between relative data for males and females was somewhat reduced. Further, males and females employed significantly different cadences for the intervals shorter than 60 seconds duration, however both cadences and physiological intensities were similar for the longer duration intervals.

The power output requirements of the cycling stage within draft-legal junior triathlon are highly variable, with the employed race tactics depending on a wide range of variables (2). In addition, each course is highly variable, consisting of an entirely different circuit profile. Therefore it is not adequate to prepare for such a race in this competition by simulating a previous race in training (i.e. with the aid of performance times or race power outputs through power meter analysis). Instead, developing junior triathletes should aim to be physically superior by improving their capability to produce power across both aerobic and anaerobic intervals (8), which is of high importance to draft-legal triathlon racing (3). The current study described the mean cycling power outputs of junior triathletes in the power profile, but also highlighted the power outputs of the best performer for both sexes. Therefore, the current data should be used as a set of normative values for regular cycle-based testing in these developing athletes. Developing junior triathletes and their coaches should aim initially to have power outputs similar to the group mean. Secondly, athletes should aim to produce power outputs equal to that of the best performer and beyond, which would ensure that they can meet the demands of any competition situation and a greater opportunity for successful performance.

The use of the power profile test combined with the the data in the current study may help an athlete to identify specific weaknesses in their cycling ability. Such an example may be where an athlete performs well relative to their peers in the longer intervals but does not possess the anaerobic power to perform well in the short duration intervals. This result would highlight the need for more maximal sprint training and perhaps resistance training exercises which also serves to improve cycling sprint performance (16). Another advantage of regular power profile testing is that the results can be useful for a coach to construct an informed training program for an athlete in relation to their current level of fitness.

Along with a set of normative values for athletes and coaches to utilise, this study provides normative cycling power functions (see equations in Figure 1) for high performing junior triathletes. These power functions have a useful application for training and performance testing and have not previously been reported for such a cohort. Importantly, the power function allows for estimation of power outputs across any duration not explicitly assessed within the test protocol or for individuals that have not undertaken a power profile. By simply inserting the ‘x’ value of the duration of interest, the power functions provided can be used to estimate normative maximal mean power output across any duration between 5–600 seconds. Data may also be extrapolated beyond these limits if desired, for example, comparisons of functional threshold power across 20 or 60 minutes (1) would require insertion of an ‘x’ value of 1200 or 3600, respectively. However, it should be noted that estimates may become increasingly inaccurate for durations that lie further from the explicitly measured 5-600 second efforts of the power profile. Nevertheless, such estimates have strong implications for coaches who may limited for time within training camps and cannot conduct a power profile assessment for 50 minutes with each individual athlete. Instead, the coach may choose several efforts of any duration and compare these to the normative power functions ($W \cdot kg^{-1}$) established in the current study. Coaches and athletes also have the option to compare recordings from their mobile power meters during field-based training and/or during races, with the normative power functions established in this study.

The power outputs were significantly higher in males compared to females and these differences still existed after adjustments for body mass. Interestingly, mean and peak cadences were significantly lower in females compared to males for most intervals lasting less than 60 seconds. Considering gears were able to be freely selected by the athletes, this suggests that the females preferred to perform shorter intervals at a lower cadence compared to the males. It is difficult to speculate if the males would have performed better in a gear with more resistance, or if the females would have performed better in a gear with less resistance. In contrast, males and females chose a similar cadence in all of the intervals lasting 60 seconds or longer. Also, mean heart rates were similar between the sexes across the longer duration efforts, suggesting both sexes self-selected similar relative cycling intensities.

An important limitation of this study was that the study population consisted of only one fifth of the triathletes competing in the Australian National Junior Triathlon Series. Indeed, a larger sample size would make for a stronger set of normative data. Nevertheless, the current study contained a broad spectrum of athletes, including the complete squad of two state triathlon bodies. The study also includes both males and females who have gone on to compete in the under 23 world triathlon championships and the senior elite category of the International Triathlon Union World Triathlon Series. Hence, coaches can have confidence that the data presented on the best performing athletes were of a high standard, however, there may be better performing athletes who could not be included in this study. Another limitation of the study was that the power profile protocol measured the power outputs from a rested state, rather than a fatigued state, which would be more specific to a triathlon scenario. The ability to perform anaerobic efforts under fatigue would be another useful indication of a draft-legal triathlete's cycling ability.

PRACTICAL APPLICATIONS

The data described herein can be used as a set of normative values and normative power functions for developing elite junior triathletes with the goal to perform well in draft-legal competitions. With both the mean and best performing male and female power outputs and resultant power functions clearly defined across the power profile, athletes can use these values and/or equations as a training goal, or to help them identify their strengths and weaknesses relative to their peers, which will be useful to inform training prescription. Overall, it allows informed, evidence based decisions to be made by technical and conditioning coaches in regard to the interpretation of cycling assessment and the cycling program design of national level junior triathletes.

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Conflict of Interest: There is no conflict of interest pertaining to the published data.

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Table 1. Mean power output measures of the group mean and the best performer expressed in both absolute and relative terms.

	Interval (s)	**Group (W)**	**Best (W)**	**Group (W·kg^{-1})**	**Best (W·kg^{-1})**
Males	6	783 ± 134	1000	11.9 ± 1.9	15.7
	15	768 ± 118	920	11.7 ± 1.4	14.5
	30	609 ± 101	761	9.2 ± 1.1	12.0
	60	470 ± 65	519	7.2 ± 0.8	8.2
	240	323 ± 38	333	4.9 ± 0.4	5.2
	600	287 ± 34	321	4.4 ± 0.4	5.0
Females	6	554 ± 92*	697	9.7 ± 1.2*	10.8
	15	510 ± 89*	654	8.9 ± 1.1*	10.1
	30	437 ± 75*	550	7.6 ± 0.9*	8.5
	60	349 ± 56*	455	6.1 ± 0.8*	7.0
	240	248 ± 39*	302	4.4 ± 0.7*	4.7
	600	214 ± 37*	271	3.8 ± 0.6*	4.2

Data is presented as mean ± standard deviation. s = seconds, W = watts, W·kg^{-1} = watts per kilogram of body mass. *Significantly (P<0.05) lower than males for respective interval duration.

Table 2. Peak power output measures of the group mean and best performer expressed in both absolute and relative terms.

	Interval (s)	Group (W)	Best (W)	Group (W·kg^{-1})	Best (W·kg^{-1})
Males	6	1011 ± 178	1346	15.3 ± 1.9	19.3
	15	962 ± 170	1234	14.6 ± 2.1	17.7
Females	6	674 ± 116*	864	11.8 ± 1.6*	13.4
	15	624 ± 114*	796	10.9 ± 1.4*	12.3

Data is presented as mean ± standard deviation. s = seconds, W = watts, W·kg^{-1} = watts per kilogram of body mass. *Significantly ($P<0.05$) lower than males for respective interval duration.

Table 3. Mean and peak cadence measures of the group mean and best performer.

	Interval (s)	**Mean: Group ($r \cdot min^{-1}$)**	**Mean: Best ($r \cdot min^{-1}$)**	**Peak: Group ($r \cdot min^{-1}$)**	**Peak: Best ($r \cdot min^{-1}$)**
Males	6	100 ± 9	92	118 ± 11	124
	15	112 ± 12	110	122 ± 17	161
	30	113 ± 10	113		
	60	109 ± 11	113		
	240	103 ± 11	113		
	600	98 ± 10	101		
Females	6	93 ± 11	98	108 ± 10*	116
	15	103 ± 8*	110	110 ± 10*	119
	30	102 ± 9*	108		
	60	103 ± 5	103		
	240	99 ± 7	100		
	600	99 ± 6	97		

Data is presented as mean ± standard deviation. $r \cdot min^{-1}$ = revolutions per minute, s = seconds. *Significantly ($P<0.05$) lower than males for respective interval duration. Peak cadence was not considered to be of relevance for intervals of >15 seconds.

Figure Captions

Figure 1: Power curves and power functions of the group means and best performing male and female athlete across the power profile tests.