Seasonal variation in calculated glycolytic power in a professional road cyclist

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Headline

The current body of scientific research on the physiological aspects of professional and elite road cycling predominantly examines key metrics of the aerobic metabolism such as the maximal oxygen consumption ($\dot{V}O_{2\max}$) and the maximal lactate steady state (MLSS) (1,2). Although road cycling is primarily an aerobic sport, cyclists rely on anaerobic metabolism to generate high power outputs during critical race phases, such as during breakaways or in the final sprint (1,3,4). Surprisingly, scientific data on the characteristics of the anaerobic metabolism, such as the maximal glycolytic power ($v\mathrm{La}_{\max}$) in this cohort is scarce. Furthermore, while the effects of endurance training on the characteristics of aerobic metabolism are well-documented in the scientific literature (5–7), its impact on $v\mathrm{La}_{\max}$ and seasonal variation of $v\mathrm{La}_{\max}$ remains underexplored.

Aim of the paper

The aims of the current study are to calculate the maximal glycolytic power ($v\mathrm{La}_{\max}$) in an elite cyclist, and to explore the seasonal variation in the key metrics of the aerobic and anaerobic metabolism. Our methodology and results can be used by coaches to investigate the seasonality of these parameters and to optimize training.

Methods

The data for this study was retrieved from a case study of an elite road cyclist (8). This study describes the training and testing program in a 37-year-old professional cyclist over a 58-week period. The cyclist performed incremental cycling tests on the Lode Excalibur Sport ergometer (LodeBV, Groningen, Netherlands) to determine the $\dot{V}O_{2\max}$, the maximal aerobic power ($\mathrm{W}_{\max}$) and the power output at a blood lactate concentration (BLC) of 3 $\mathrm{mmol{\cdot}l^{-1}}$ (PL3). PL3 was determined using a submaximal continuous incremental cycling test. The test started at 125W, and the workload was increased by 50W in 5 min steps. At the end of each 5-min bout, a capillary blood sample was taken to determine the BLC (Biosen C-line, EKF Diagnostics, Berleben, Germany). The test was stopped when a minimal BLC of 3 $\mathrm{mmol{\cdot}l^{-1}}$ was achieved. PL3 was extrapolated from the relationship between BLC and power output. After 10 minutes passive recovery, a ramp test with spirometry (Oxycon pro, Erich Jaeger, Hoechberg, Germany) was performed to assess $\dot{V}O_{2\max}$. The initial workload was set at 200 W and increased by 25W every minute until exhaustion. The highest 30-s average $\dot{V}O_2$ measurement was used to determine $\dot{V}O_{2\max}$. The maximal aerobic power ($\mathrm{W}_{\max}$) was determined as the average power output during the last minute of the ramp test.

The experimental data was used to feed a mathematical model of muscle metabolism (INSCYD GmbH, version 2.0, Salenstein, Switzerland). The mathematical model has been validated for the determination of $\dot{V}O_{2\max}$ and MLSS in well-trained cyclists (9,10). The data used for the calculations were: sex, body mass, $\dot{V}O_{2\max}$ and PL3. The maximal lactate accumulation rate ($v\mathrm{La}_{\max}$) could be calculated from the available data as the power at a fixed lactate concentration (PL3) for a given exercise duration is a function of $\dot{V}O_{2\max}$ and $v\mathrm{La}_{\max}$ (11,12). The original study reported body weight exclusively for the first and final tests. To estimate body weight for the intermediate tests, a linear regression was applied (Table 1). No body composition data was available. The INSCYD's algorithms use body fat percentage in the calculations of the key physiological metrics. Therefore, a fixed body fat percentage of 9% was used. This value was chosen based on the scientific data of professional road cyclists of simular body size and mass (1,13). The body fat percentage for each subsequent test was interpolated based on the changes in body weight. It was assumed that the weight changes could be attributed to changes in fat mass. The individual body fat percentage may differ from the calculated values. Therefore, we calculated the effect of changes in body fat (±1%) on the power at MLSS (PMLSS) and $\mathrm{Fat}_{\max}$ ($\mathrm{PFat}_{\max}$). According to these calculations, the PMLSS and $\mathrm{PFat}_{\max}$ was affected by ±4 W, which is lower than the typical error for PMLSS and $\mathrm{PFat}_{\max}$ measurements (14,15). To obtain a precise fit of the calculated data with the measured data, gross efficiency (GE) was adjusted from the default value (22.97%) to 19.94%, whereas all other settings were kept at the software's default values (Table 2).

Training data were extracted from the study by Rønnestad and Hansen (8) and described as follows: training volume per week, time spent in 3 training zones expressed in hours and as a percentage of the total training time (Table 4). A 3-zone intensity distribution model was adopted based on the percentage of maximal heart rate ($\mathrm{HR}_{\mathrm{peak}}$) with zone 1: 60-82% of $\mathrm{HR}_{\mathrm{peak}}$, zone 2: 83-87% of $\mathrm{HR}_{\mathrm{peak}}$ and zone 3: 88-100% of $\mathrm{HR}_{\mathrm{peak}}$ (8). Lucia TRIMP (luTRIMP) scores were calculated from the time spent in the three training zones (16).

Results

Figure 1 illustrates the seasonal variation of $\dot{V}O_{2\max}$ and $v\mathrm{La}_{\max}$. $\dot{V}O_{2\max}$ ranged between 73.8-87 ml $\mathrm{O2{\cdot}kg^{-1}{\cdot}min^{-1}}$ and $v\mathrm{La}_{\max}$ between 0.49-0.8 $\mathrm{mmol{\cdot}l^{-1}{\cdot}s^{-1}}$ respectively. The highest $\dot{V}O_{2\max}$ (87 ml $\mathrm{O_2{\cdot}kg^{-1}{\cdot}min^{-1}}$) was achieved at the end of the season, whereas the highest $v\mathrm{La}_{\max}$ was achieved at the start of the training period (0.8 $\mathrm{mmol{\cdot}l^{-1}{\cdot}s^{-1}}$). Figure 2 illustrates the seasonal variation of PMLSS and $\mathrm{PFat}_{\max}$, ranging between 265-346W and 170-233W respectively. The highest PMLSS and $\mathrm{PFat}_{\max}$ were achieved at the end of the season.

The trainingload for each zone was: zone 1 – 450 AU, zone 2 – 246 AU, and zone 3 – 215 AU. Zone 1 accounted for 49.35% of the total trainingload. Zone 2 and zone 3 contributed 27.01% and 23.63% respectively to the total trainingload (Table 4).

Table 1. Anthropometric, physiological and calculated data. The experimental data is retrieved from (8).

Data retrieved from Rønnestad and Hansen (2018)					
Test	Week	Height(cm)	Mass(kg)	$\dot{V}O_{2\max}$ (ml·min^{-1}·kg^{-1})	PL3 (W)
1	1	175	71.3	73.8	257
2	10			79.8	304
3	20			83.7	309
4	37			86.4	304
5	45			84	323
6	51			81	308
7	58	175	68	87	333

Table 2. Applied default settings in the INSCYD software for body composition.

Test nr	Body fat (%)	Body water (% body mass)	Total muscle mass (% body mass)	Muscle mass used (% muscle mass)	Lactate distribution space (% body mass)
1	9	68.88	42.42	65	50.63
2	8.27*	69.38	42.73	65	50.99
3	7.52*	69.89	43.04	65	51.37
4	6.23*	70.76	43.58	65	52.01
5	5.61*	71.19	43.84	65	52.32
6	5.13*	71.51	44.95	65	52.56
7	4.59*	71.88	44.27	65	52.83

*Values were calculated by linear extrapolation based on the reported weight loss (see methods for more information).

Table 3. Calculated data are expressed as the rate of change per week between tests (Δ/t) (see methods for more information).

Calculated data using INSCYD software *					
Test	Week	$\Delta v\mathrm{La}_{\max}$/t (mmol·l^{-1}·s^{-1}·week^{-1})	$\Delta\dot{V}O_{2\max}$/t (ml·min^{-1}·kg^{-1}·week^{-1})	$\Delta\mathrm{Fat}_{\max}$/t (W·week^{-1})	ΔMLSS/t (W·week^{-1})
1	1				
2	10	-0.03	0.67	4.4	5.8
3	20	0.01	0.39	0.2	0.6
4	37	0.01	0.16	-0.4	-0.4
5	45	-0.03	-0.3	2.5	2.5
6	51	0	-0.5	-2	-2
7	58	0	0.86	3.7	3.7

Table 4. Training data is retrieved from this publication (8).

Training period	Nr weeks	Avg. Weekly volume h	Time in Z1 h (% weekly volume)	Time in Z2 h (% weekly volume)	Time in Z3 h (% weekly volume)
1	9	12.75	81.25 (71)	24.75 (22)	8.75 (8)
2	10	11.83	72.5 (61)	18.5 (16)	15.5 (13)
3	17	11.81	139 (69)	30.25 (15)	19 (9)
4	8	16	90.5 (71)	25.5 (20)	8 (6)
5	6	5.88	19 (54)	7.5 (21)	6.75 (19)
6	8	11.29	46 (58)	16.5 (21)	13 (16)
Total	58	678	451.6 (67)	124 (18)	69 (10)

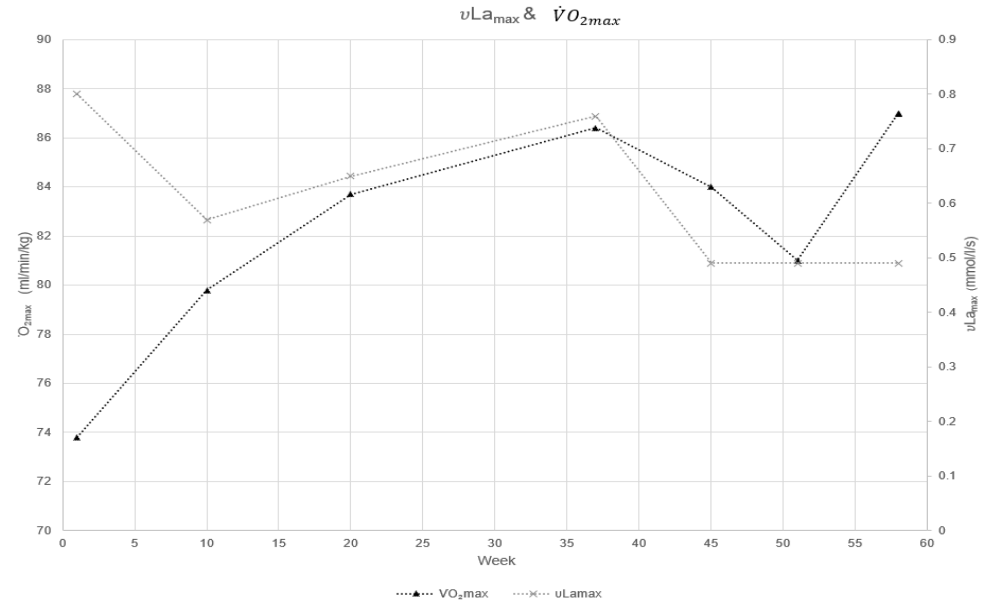

Fig. 1. $\dot{V}O_{2\max}$ **(ml min^{-1}·kg^{-1}) and** $v\mathrm{La}_{\max}$ **(mmol·l^{-1}·s^{-1}) at seven test occasions during a cycling season in a professional cyclist.**

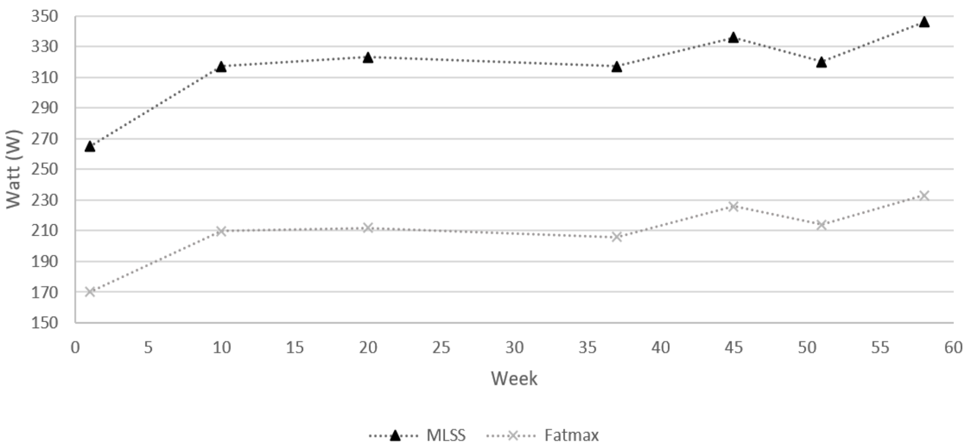

Fig. 2. The power output at MLSS (W) and Fat$_{\max}$ (W) at seven test occasions during a cycling season in a professional cyclist.

Discussion

The present case study extends the main findings reported in the case study by Rønnestad and Hansen (8), which described the seasonal variation in $\dot{V}O_{2\max}$ and PL3 in a 37-year-old elite cyclist. The methodology used in the current study allowed for the calculation of additional physiological metrics, such as the $v\mathrm{La}_{\max}$, PMLSS and PFat$_{\max}$ to provide a more comprehensive view of the cyclist's metabolic profile.

$v\mathrm{La}_{\max}$, as an estimate of maximal glycolytic power, has recently received more attention in the scientific literature (12,17–22). However, data of $v\mathrm{La}_{\max}$ values in elite cyclists remain scarce. To our knowledge, this is the first study that explores the seasonal variation in $v\mathrm{La}_{\max}$ in an elite cyclist. In this study, the calculated $v\mathrm{La}_{\max}$ ranged between 0.49 and 0.8 mmol·l^{-1}·s^{-1} aligning closely with the values typically observed in endurance athletes (17,22,23). Higher $v\mathrm{La}_{\max}$ values have been found in track cyclists (∼0.97 mmol·l^{-1}·s^{-1}) (21), lower values (0.2– 0.5 mmol·l^{-1}·s^{-1}) have been reported in marathon runners, road cyclists and long-distance triathletes (17,18,24,25). The current study demonstrates that $v\mathrm{La}_{\max}$ is highly adaptable during the season. To the best of our knowledge, only one scientific study investigated the effect of different training regimens on $v\mathrm{La}_{\max}$ (22). The authors observed that sprint interval training with 30" sprints (SIT) reduced $v\mathrm{La}_{\max}$ by 15% over a 6-week training period, whereas moderate intensity endurance training had no effect on $v\mathrm{La}_{\max}$. Further studies are required to determine the most effective training protocols for optimizing $v\mathrm{La}_{\max}$.

In the current study, the cyclist performed a low volume (only ∼12h per week) high-intensity training program, with

$\sim$50% of the training load performed in the moderate and high-intensity domain. This program resulted in large improvements in $\dot{V}O_{2\max}$, PMLSS and $\mathrm{PFat}_{\max}$ in an already highly trained individual. This observation aligns with the current scientific knowledge on high-intensity training as an effective training method to increase $\dot{V}O_{2\max}$ (for review see (5)).

To fit the calculated data with experimental data, we adjusted the GE from the default value ($\sim$23%) to $\sim$20%. According to the literature, GE in elite cyclists is typically found in the 22-23% range (13,26,27). This discrepancy might be related to the fiber type distribution in this athlete. The relatively high glycolytic power in this endurance athlete (0.8 $\mathrm{mmol \cdot l^{-1} \cdot s^{-1}}$) indicates for a higher proportion of type 2 fibers (28) and it has been demonstrated that athletes with higher proportion of type 2 fibers have lower GE (29). Secondly, it has been observed that GE and $\dot{V}O_{2\max}$ are inversely correlated in world-class endurance cyclists (26). In this case study, the cyclist had systematically $\dot{V}O_{2\max}$ values >80 ml $\mathrm{O_2 \cdot kg^{-1} \cdot min^{-1}}$ which are among the highest values in endurance cyclists documented in the scientific literature (13,26).

Some limitations in the present study should be acknowledged. The calculation of $v\mathrm{La}_{\max}$ was based on only two data points: $\dot{V}O_{2\max}$ and PL3. While this approach allows the assessment of $v\mathrm{La}_{\max}$, it is sensitive to measurement errors. Inaccuracies in $\dot{V}O_{2\max}$ and PL3 might lead to errors in the calculation of $v\mathrm{La}_{\max}$. Considering the typical error of $\dot{V}O_{2\max}$ and lactate threshold assessments of ±3% (43), we calculated a maximal error in $v\mathrm{La}_{\max}$ of ±0.15 $\mathrm{mmol \cdot l^{-1} \cdot s^{-1}}$. This range exceeds the typical error observed in $v\mathrm{La}_{\max}$ (± 0.05 $\mathrm{mmol \cdot l^{-1} \cdot min^{-1}}$) (30), and it is therefore possible that these measurement errors could affect our calculations. Secondly, body fat percentage data was not available from the original dataset. Body fat percentage impacts body water content and the lactate distribution space. An estimate of the lactate distribution space is required to precisely calculate the glycolytic energy contribution based on BLC. To overcome this issue, a fixed body fat percentage has been used and changes in body mass during the season were attributed to changes in body fat. This procedure might have introduced errors in our calculations. However, according to our calculations, changes in body fat percentage of ±1% accounted for a maximum error of ±4 W at PMLSS and $\mathrm{PFat}_{\max}$. This error is lower than can be expected from gold standard procedures for PMLSS and $\mathrm{PFat}_{\max}$ determination (17,18).

Finally, as the current study is a descriptive case study, generalization of our results should be done with care. To investigate a causal relationship between training parameters and the key metrics of the athlete's metabolic profile, more scientific research, particularly training intervention studies, is needed.

Practical applications

- This study has demonstrated an innovative methodology to calculate a comprehensive metabolic profile from basic physiological metrics such as the $\dot{V}O_{2\max}$ and lactate thresholds.
- The mathematical model used in this case study allows for performance projections providing coaches with valuable insight to optimize the training planning.

Conflict of interest

Reinout Van Schuylenbergh is consultant for INSCYD GmbH. No funding was received for this research.

Data availability

The data that support the findings of this study are shown in this manuscript.

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