Model of 30-s sprint cycling performance: Don't forget the aerobic contribution!

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Abstract: Introduction: Current practice in coaching track cycling sprint athletes is a focus on a very narrow band of power output from 1-4 seconds. However, there is a small oxidative contribution to sprint performance as short as 10-s, and this contribution increases as a rider competes in multiple events. All Olympic track cycling events demand repeated sprint performance! Purpose: This study models sprint-cycling performance to investigate the role of durations requiring a high oxidative contribution to energy supply and their relationship to sprint-cycling power durations. It hypothesizes power at endurance durations are strongly related to power at sprint durations, and further, these relationships may be nonlinear and saturable. Methods: Power meter data was used from 89 participants (192 datasets) to model fit the data using 4 different models (exponential, linear, parabolic, and power) using total least-squares. All data was based on a (0,0) start point acknowledging neither glycolytic or oxidative pathways operate independently. Dependent variables were 15 and 30 second power, and predictor variables 2, 8 and 20 minute power. Results: All four models yielded high r2 values (r2 > 0.81), and the exponential and linear models in particular. Strong correlations for all models demonstrates the role of oxidative power duration on performance over short durations. The linear model was the best model based on consistent, high r2 values and model simplicity, validating the first hypothesis, but nullifying the second. Conclusion: The results show maximal performance in sprint-cycling durations of 15 and 30 seconds are strongly related to maximal performance in 2, 8, and 20 minute power, and training at these durations does not diminish performance, and with a season, training maximally at these durations complements performance. These results match physiological studies showing oxidative pathways play a major role in sprint and repeated sprint efforts.

Keywords: Cycling, Track Sprinting, Power Meter, Modelling, Performance, Coaching

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1. INTRODUCTION

The power-duration curve represents the maximum power an athlete can sustain for a given duration (Burnley et al., 2016), and is used regularly as a training tool for competitive cyclists (Weyand et al., 2006). Various models exist to populate the curve with maximal efforts at various durations, and the best of these models test durations from 1-5 seconds, 30-60 seconds, 3-8 minutes, and greater than 15 minutes (Burnley et al., 2016, Morton, 1996). Models are used to fill in the gaps between true maximal efforts. The power duration curve can be used to determine areas where more testing is needed, to ascertain strengths to be maintained and weak areas to be trained (Morton, 2006, Sanders et al., 2017). Once a well-developed power duration curve is established for a rider it can be used to guide an athlete towards events where they have the best chance of success, and to guide their tactics in racing, in particular pacing, and especially in events with a stochastic nature (Morton et al., 2004, Sanders et al., 2017).

Current thinking among sprint cycling coaches, holds power for sprint events is supplied mainly by the phosphocreatine system, to a lesser extent, non-oxidative glycolytic pathways, with limited contribution from oxidative pathway although no research using power meter data, nor physiological estimates has been applied to sprint cycling competition. However, recent reviews show this belief may not hold (Ferguson et al., 2021). For example, measures of lactate after a 10-s test showed glycolytic processes occur well before phosphagen stores are depleted (Jacobs et al., 1983). Duffield, Dawson and Goodman estimate the energy contribution using lactate measures, and phosphocreatine degradation estimates to 100-m athletics sprinting, suggesting a 8.9 (±3.3)% oxidative contribution for males and 10.9 (±5.8)% for females (Duffield et al., 2004). Therefore, it is clear sprint events utilise all energetic pathways, the impact of muscle fibre type on performance remains to be elucidated.

For instance, data by Nummela and Rusko (Nummela et al., 1995) indicate when energy release was compared between sprint and endurance runners, there were differences only in the second half of the run, where sprinters relied more, but not solely, on oxygen independent pathways. Considering the approach to testing and training sprint cyclists, this result may reflect more on athlete preparation and the potential of aerobic conditioning.

Based on data showing glycolytic and oxidative contributions to sprint performance, this research used power meter data to determine whether increasingly aerobic dominated power durations have a relationship with performance at sprint duration, and vice versa. They include zero power (0,0) to avoid models indicating the possibility of having sprinting power with zero endurance, or vice versa. Overall, it hypothesises sprint and endurance power are strongly, and possibly nonlinearly, related, demonstrating the need and potential for endurance training in sprint event preparation.

2. METHODS

2.1 Study Design

The study uses retrospective data to develop models of sprint cycling performance as a function of anaerobic and aerobic power metrics. The data was supplied to the lead author in his capacity as a coach, sport science consultant, beta tester of power meter analysis software, and researcher by individual cyclists from 2006 to 2020. The model proposed hypothesizes:

- Aerobic and anaerobic power are strongly related within individual cycling athletes, contrary to current coaching assumptions (Baker et al., 2016, Jacobs et al., 1983, Medbø et al., 1989, Serresse et al., 1988, Smith et al., 1991, Withers et al., 1991, Yang et al., 2019)
- This relationship is nonlinear and saturable indicating a strong inter-relationship with aerobic power exists only up to a certain level, after which returns diminish.

These hypotheses build on the physiological results showing even short sprint duration efforts utilise a range of energy pathways including endurance related oxidative pathways (Ferguson et al., 2021). The first hypothesis would indicate the ability to improve sprinting power and performance via endurance training, linking physiology to performance. The second hypothesis would characterise this response and at what power levels diminishing returns commenced.

2.2 Participants

A total of 192 datasets from 89 participants, were used on the basis of having at least six months of consistent data, reflecting maximal power efforts for 15-s and 30-s as a performance based measure of sprint cycling, and 2-min, 8-min, and 20-min. Several participants provided data over several years and each year was added as a separate dataset. Table 1 shows the subject data and demographics. All subjects gave informed consent to use their data for the research on the condition it would be anonymised and thus ethics approval was not sought.

TABLE 1. Participant data with male (M) and female (F) reporting median and interquartile range (IQR)

	M	**F**	**Age (years)**	**Weight (kg)**
All	75	14	29.64 (14.65)	72.2 (9.70)
Male	75		30.54 (15.07)	73.97 (9.05)
Female		14	23.88 (11.05)	60.92 (5.38)
Sprint	15	5	30.15 (17.84)	79.07 (11.40)
Endurance	60	9	29.5 (13.51)	70.0 (7.92)

2.3 Procedures

Riders performed training and racing using a bicycle mounted power meter. Power, was measured in 1-s intervals, recorded on a bicycle computer, and uploaded to the online database TrainingPeaks™ (TrainingPeaks, Boulder, CO). Data was synched with the sports data analysis software WKO5™ Build 576 (TrainingPeaks, Boulder, CO).

Sprint power was measured as 15-s or 30-s power in W/kg is hypothesised to be a nonlinear function of endurance power in W/kg over any one of 2-min, 8-min, and 20-min. Using W/kg normalised power output across sex and overall size. Four functions were used to define the relationship in this study, seeking to find a potential best model, and are described in Table 2.

TABLE 2. Four models proposed

(1)	**Exponential**: W/kg 15/30-s = $(h\cdot(1-\exp^{(-A\cdot x)}))$
(2)	**Linear** : W/kg 15/30-s = $(a0\cdot x)$
(3)	**Parabolic**: W/kg 15/30-s = $(a1\cdot x^2+a2\cdot x)$
(4)	**Power Equation**: W/kg 15/30-s = $(a3\cdot x^b)$

In Table 2, x is one of W/kg 2-min, W/kg-8min, or W/kg 20-min in Equations (1)-(4), and all other terms (a0, a1, a2, a3, A, h, b) are constant coefficients found by identifying the best function for each case from the measured data.

Equation (1) was a saturating exponential model, Equation (2) was a linear relationship through the zero power point (0,0), Equation (3) is a parabolic function with a saturating behaviour for some sets of coefficients, and Equation (4) is a power law relationship, which also saturates. Each of Equations (1)-(4) start at the point (0,0), a null power point. The 0.0 point acknowledges all energetic pathways are functioning at a given time, and both start at point 0. Equally, Equations (1), (3) and (4) all saturated past highly oxidative power durations, x, depending on the coefficients identified from the data, indicating diminishing to no return in sprinting power for increasing oxidative endurance power past a certain level.

The model coefficients (a0, a1, a2, a3, A, h, b) in Equations (1)-(4) are identified using total least squares (Golub et al., 1980, Markovsky et al., 2007) because there is test variability and error in both the x (oxidative power over 2-min, 8-min, or 20-min) and y axis (sprint power over 15-s or 30-s) measured power output metrics. Total least squares minimises the perpendicular distance from any point to the line or curve of the formulated Equations (1)-(4)) model. The traditional linear model using Equation (2) is included as the simplest possible model and to test the second hypothesis.

2.4 Analyses

All models were assed in Matlab version R2021a (The MathWorks Natick, MA, USA). Models were identified separately for 15-s power and 30-s power as a function of each of 2-min, 8-min, and 20-min endurance power. Each model was utilised for three different cohorts: all riders together; sprinters alone; and endurance cyclists alone. Each of the nonlinear models (1, 3 & 4) is compared to a standard linear model to assess if added complexity adds model quality, per the second hypothesis.

Model quality was assessed by total least squares correlation coefficient r^2. A higher r^2 value indicated a better model, although very small differences may be ignored in favour of model complexity. A 'best model' had the highest r^2 for both 15-s and 30-s power in W/kg across all riders, and either sprint or endurance riders, for which models are identified, and thus was the most consistent in performance.

3. RESULTS

Figure 1 illustrates models for either 15-s or 30-s W/kg with 2-min, 8-min and 20-min W/kg as the input predictor variable for the exponential (Equation (1)) and linear (Equation (2)) models, with the other nonlinear models not shown as they are very similar to the Exponential Model. Data from sprint cyclists are presented first for each duration and then combined sprint and endurance cycling data. The line of best fit is shown in each case.

Figure 2 shows all the total least squares Linear Model (Equation (2)) lines from Figure 1 without data points to enable comparison. Table 3 shows all high r^2 value results for all models and cohorts, showing how aerobic durations contribute to both sprint durations considered. These results support the primary hypothesis that oxidative energy supply has a strong influence and relationship to sprint ability and power, and quantifies these relationships for different types of riders. Table 3 also shows the Linear Model of Equation (2) is the best model based on the consistently highest r^2 values and minimal model complexity, invalidating the second hypothesis of a saturating effect or relationship, which is only lightly evident in Figure 1.

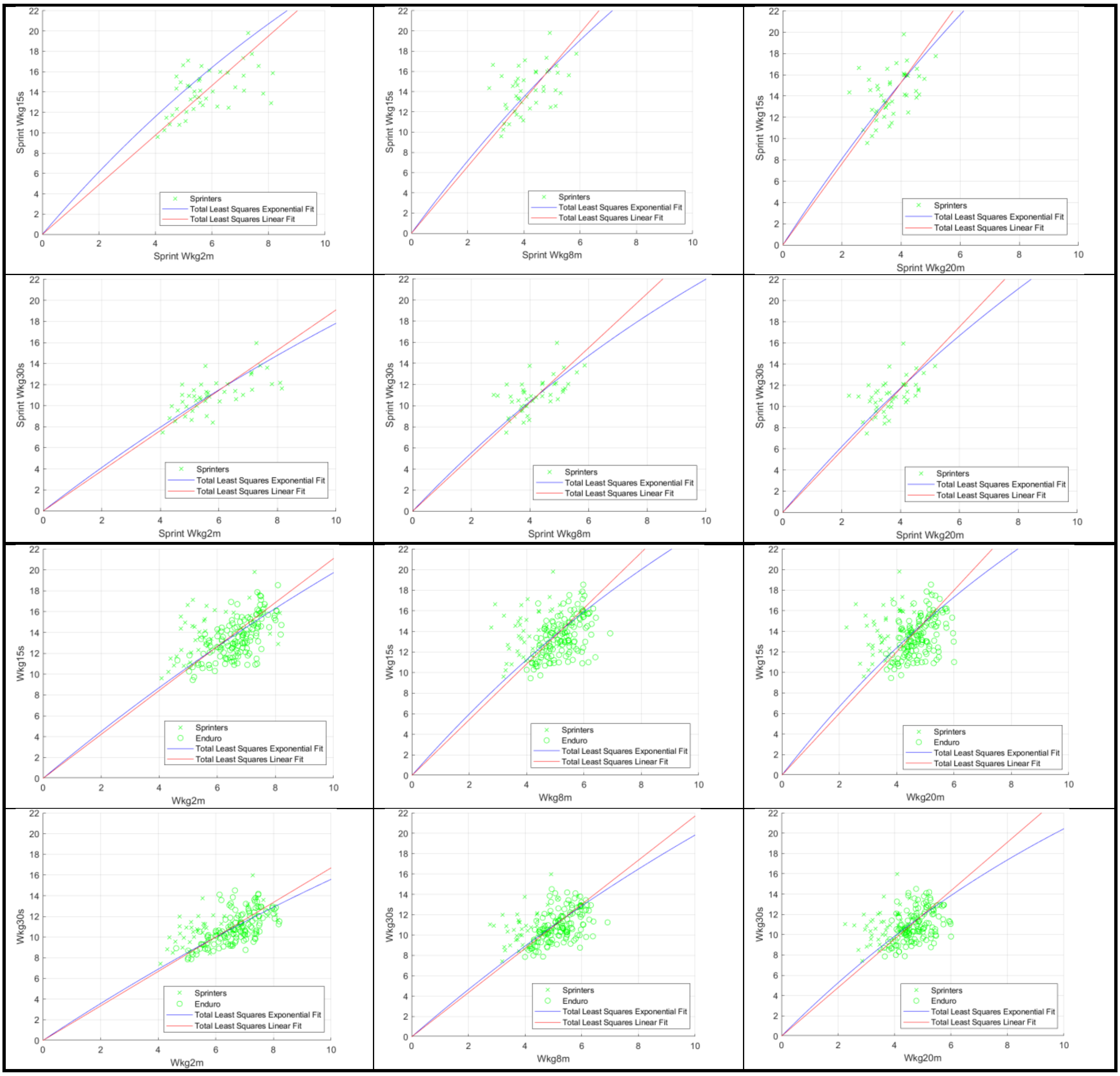

FIGURE 1. Exponential model (Equation (1)) and Linear (Equation (2)) models for: Row 1: W/kg-15s with Sprinter data only; Row 2: W/kg-15s with all riders; Row 1: W/kg-30s with Sprinter data only; Row 2: W/kg-30s with all riders.

TABLE 3: All model identification and r2 results

		Exponential			Linear		Parabolic			Power		
Data	Group	h.	A	r^2	Slope	r^2	a1	a2	r^2	a	b	r^2
30s~20min	All	41.87	0.067	**0.80**	2.39	**0.81**	0	2.39	**0.81**	2.39	1	**0.82**
30s~8min	All	58.96	0.041	**0.81**	2.17	**0.82**	0	2.17	**0.82**	2.18	1	**0.82**
30s~2min	All	52.80	0.035	**0.82**	1.67	**0.83**	0	1.67	**0.83**	1.67	1	**0.83**
15s~20min	All	47.80	0.075	**0.84**	3.00	**0.85**	0	2.99	**0.85**	2.99	1	**0.85**
15s~8min	All	51.20	0.062	**0.83**	2.71	**0.85**	0	2.71	**0.85**	2.71	1	**0.85**
15s~2min	All	68.50	0.034	**0.83**	2.11	**0.84**	0	2.11	**0.85**	2.11	1	**0.85**
30s~20min	Sprint	58.47	0.056	**0.88**	2.92	**0.90**	0	2.93	**0.90**	2.93	1	**0.90**
30s~8min	Sprint	48.73	0.060	**0.88**	2.58	**0.89**	0	2.58	**0.89**	2.58	1	**0.89**
30s~2min	Sprint	56.40	0.038	**0.86**	1.91	**0.87**	0	1.91	**0.87**	1.91	1	**0.87**
15s~20min	Sprint	71.60	0.060	**0.92**	3.82	**0.93**	0	3.83	**0.93**	3.83	1	**0.93**
15s~8min	Sprint	62.30	0.061	**0.90**	3.30	**0.90**	0	3.30	**0.90**	3.30	1	**0.90**
15s~2min	Sprint	54.33	0.053	**0.86**	2.44	**0.87**	0	2.44	**0.87**	2.44	1	**0.87**

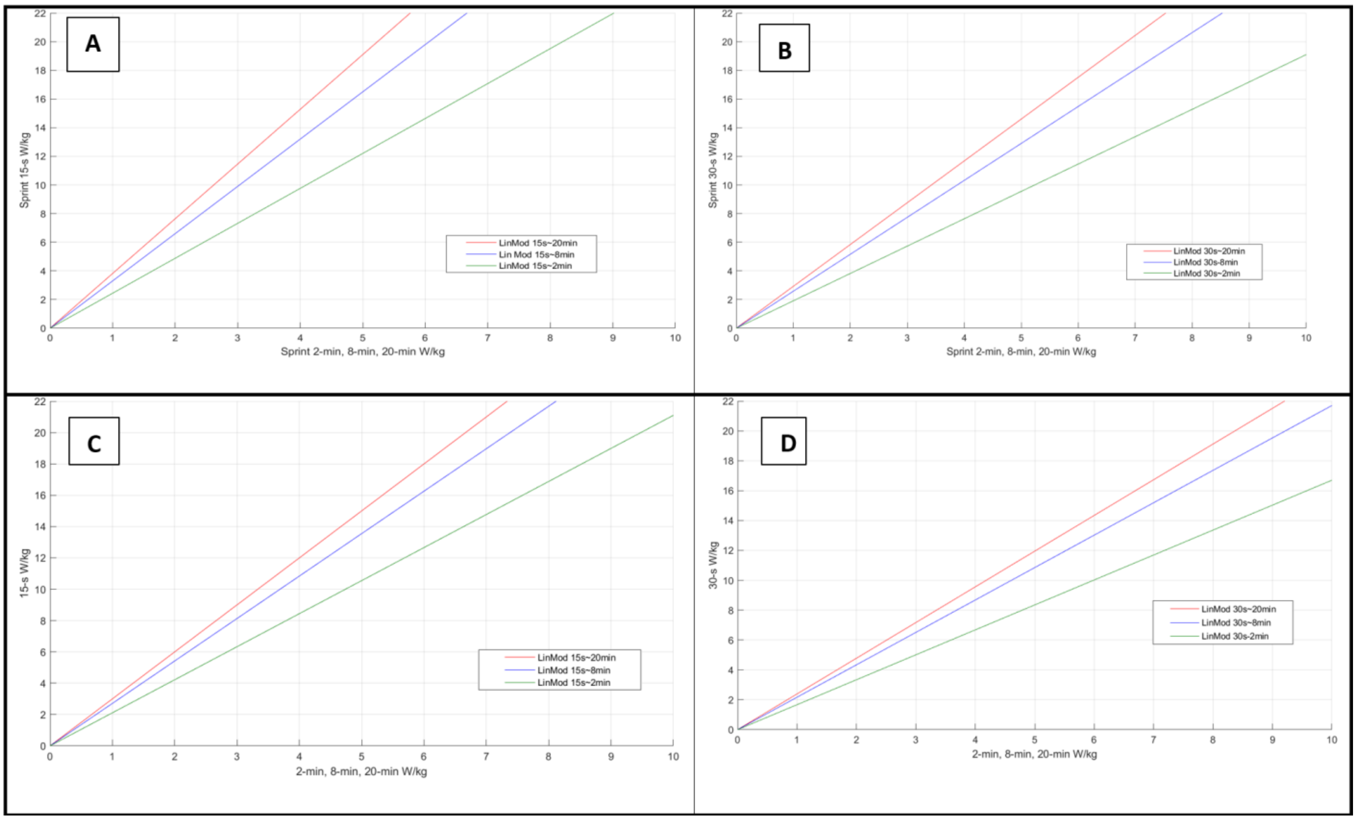

FIGURE 2. Comparison Plots for Linear model (Equation (2)) results from Figure 1. In particular, A) Sprint cyclist's 15-s W/kg, for 2-min, 8-min & 20-min W/kg; B) Sprint cyclist's 30-s power; C) All cyclist's 15-s; and D) All cyclists 30-s.

4. DISCUSSION

The purpose of this study was to model sprint cycling power as a function of endurance or oxidative driven power. The hypothesis was that durations of cycling exercise highly supplied by the oxidative energy system (2-min, 8-min & 20-min) would relate greatly with cycling exercise durations associated with sprint performance (e.g. 15 seconds & 30 seconds). This hypothesis was based on physiological literature (Borges et al., 2014, Duffield et al., 2004, Hellard et al., 2018, Pickett et al., 2018, Spencer et al., 2001), yet contrary to the current sprint cycling training approaches and framework (Haugen et al., 2019, Wiseman, 2015). These relationships between sprint duration power and oxidative pathway power were hypothesised to be strong, include the null power point (0,0), and to be nonlinear with a saturating or diminishing returns effect at higher power.

Results showed the best model to be a linear relationship between two measures of anaerobic power, and three measures of aerobic power with consistent, strong values of $r^2 = 0.81$-0.90 across all metrics and cohorts examined. The consistent and strong correlations validate the first hypothesis. The linear model of Equation (2) was best due to equivalent r^2 values, but having lower complexity.

Thus, the second hypothesis of a nonlinear saturating behaviour was not seen, which is also evident in the small differences between model lines and curves for the Linear and Exponential model coefficients in Figure 1 making them essentially linear, where all other nonlinear models were similar in shape and r^2 (Table 3). All these results are further supported by the literature on oxidative and other energy pathway utilisation in sprinting events and repeated sprint performance (Lievens et al., 2020a, Lievens et al., 2020b).

All models included the point (0,0), the null power point, which precludes other more complex models. This assumption is physiologically appropriate, where a rider could not have a measurable anaerobic watts/kilogramme, and an aerobic power of zero, or vice versa. This aspect of the model also highlights the importance of the power-duration curve, which includes very low power points, and its potential impact in training riders through long periods of development, where they would move along these lines.

Figure 2 shows differences in slope between the sprint, endurance, and overall cohort. These differences do not invalidate the overall conclusions. The difference in slopes provides a trade-off between effect for different rider types. They are likely due to differences in phenotype and resulting muscle composition and/or specific training effects. However, the overall relationships are strong in all cases, as in Table 3.

4.1. Practical Applications

Initial modelling and data suggested a level of saturation where endurance based power in W/kg would have no further effect on developing anaerobic sprint power, as encapsulated in the second hypothesis. Yet, interestingly, the linear model line suggests athletes sitting below the line should train the y axis or anaerobic power to improve, while athletes above it would benefit more from aerobic oxidative power focused training. The linear model being the best model suggests this trade off would exist at least through the relatively high power levels included in this data set of elite and sub-elite athletes.

When planning the preparation of sprint cyclists for competition where repeated-sprint performance is required, as in all Olympic level sprint events, the data presented show having a high 2-min, 8-min and 20-min power will positively related to their performance for 15 and 30s power. However, as the data covers periods of 3-12 months, this advice does not mean all durations need to be trained simultaneously. This training could be periodised, so endurance focused training predominates early in the run-in to a major event. For sprint cyclists in particular, where there is a fast drop off of sprint performance due to detraining compared to endurance athletes (Mujika et al., 2001), there is a need for regular sprint exercise to maintain their performance levels (Haugen et al., 2019).

4.2. Limitations

The major limitation of this study is the limited datasets of sprint cyclists (N = 20 of 89 total). However, the nature of sprint competition suggests a higher oxidative capacity benefits competing over multiple races and is related to recoverability (Hoffman et al., 1999, Lievens et al., 2020a). Further, and equally importantly, the results for the Sprint cohort alone in Figures 1-2, and Table 3 show strong results, so the relationships and initial hypothesis would hold, even if the exact linear model relationship changed.

A second limitation is the reliance on cross-sectional data from a 6-12 month period including competition and test events. While this choice ensures both a maximal 30-s and 20-min effort, it does not assume they happened at the same time in the training/racing period. However, in terms of estimating the effect of 20-min on 30-s performance it still shows aerobic performance at some stage of the training year for that athlete.

Future research should investigate the question of whether a sprinter can possess too much power. Does having a higher 1 or 5 second power have a lesser effect on 30-s power relative to 15s power? Further, are there differences in power duration curves in male and female sprint cyclists? Answers to this question would support training decisions for both genders, and would build on these results.

5. CONCLUSIONS

The common belief aerobic training for sprinters is detrimental appears unfounded by the strong correlations in the model results presented. These results indicate a strong linear relationship and model between 15-30 second power and three aerobic power durations from 2-min to 20-min. Even when the data are for sprint cyclists only, the relationships were still strong.

A further conclusion is captured by the linear model found, indicating no saturation of effect in the elite and sub-elite athletes studied. Thus, this training effect does not appear to significantly saturate in exponential or power law format, with those models confirming a linear relationship. Hence, the training implications would not be restricted to specific riders or capability levels.

The overall result quantifies and builds upon and is supported by physiological research showing oxidative energy pathways play a major role in sprint effort, and repeated sprint effort, events. Sprint cyclists should aim to include some form of aerobic exercise in their programme to optimise sprint performance to varying degrees over a training period leading to a key event. Coaches can use these results to place specific riders relative to the linear model lines, and train the appropriate pathway for improvement.

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