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Communication

Torque behaviour during cycling sprints from different pedalling frequencies

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1. Introduction

Professional road cycling events often result in a bunch sprint at the end of a race, where the winner is often determined by a photo finish. The development of cycling-specific technology, (i.e. measurement of power output progressed, which might help to improve sprinting qualities and tactics1,2). Torque is the force perpendicularly applied to the pedal and is in direct relation of the crank velocity (cadence) and power output. During a sprint finish in professional road cycling races power outputs of >1.200W are recorded, which highlight the importance to optimize the torque and cadence relationship. Therefore, previous research focused on determining sprint cycling properties in laboratory conditions using a variety of isokinetic, force velocity and crank load inertia cycling specific tests3. Due to technological innovations a new generation of power meters (SRM PM 9, SRM GmbH, Germany) now allows such an analysis in field conditions. Therefore, the aim of the study is, to investigate the torque-cadence and power relationship in field conditions for sprint cycling efforts (6-10s) using a variety of cadences.

2. Materials and Methods

The study's participants involved female (N=3, 23±2 years, 172±cm, 59±3 kg) and male (N=2, 27±3.5 years, 179±9 cm, 79±6 kg) athletes. For data acquisition commercially available crank power meters (SRM Powermeter 9, SRM GmbH, Germany) have been used. To avoid measurement bias by the participants perception of effort (RPE) was used for intensity prescription. The subjects were instructed to perform a twenty-minute warm up at 3/10 RPE including two short activation sprints. After the warmup participants executed five maximum sprints (RPE 10/10) on level ground over six to ten seconds duration, interspersed by >10min of active recovery at 2/10 RPE. Starting cadences for the sprints of 60, 80, 100, 110 and 120 rpm were randomly applied to avoid selection bias. The subjects were being allowed to shift during their sprints. Torque and angular velocity data were recorded with a mobile crank power meter (Powermeter 9, SRM GmbH, Germany) at 200 Hz sampling rate. A customized software (Fit File Viewer, SRM GmbH, Germany) was used to download and analyze power meter data from the head unit (SRM PC 8, SRM GmbH, Germany). Maximum torque (TQpeak), maximum on power (Pon) and one second peak power (Pmax) were detected by graphical inspection by two authors independently and in case of no agreement the third author was approached. TQpeak was defined as the mean of the two TQpeak values of a crank revolution for corresponding cadence. Pon was the highest power output recorded at the left (Angleft) and right crank angle

(Angright). Further statistical analysis was conducted in Excel (Microsoft, Version 2202) using a customized spreadsheet.

All values are presented as mean ± standard deviation. Normality was tested using Shapiro Wil ($p>.05$). A one-way analysis of variance with a Holm post-hoc procedure analyzed differences in TQpeak, Pon, Pmax, Angleft and Angright across all cadence ranges. Due to the small sample size ($N=5$) effect sizes of Cohen's d for small >.2, medium >.5 and large >.8 and mean difference (Δ) are reported.

3. Results

Table 1 involved descriptive characteristics of TQ_{peak}, P_{on}, P_{max}, Ang_{left} and Ang_{right} across all cadence ranges.

TQ_{peak} was demonstrating a large effect ($d=1.4$ to 4.0) across all cadence ranges (Δ: 25 to 72 Nm). P_{on} demonstrated a small to large effect ($d=.3$ to 1.1) across all cadence ranges (Δ: -16 to 189 W). P_{max} indicated a small to large effect ($d=.1$ to 0.96) for all cadence ranges (Δ: 11 to 100 W). Ang_{left} and Ang_{right} recorded only small effect ($d=.07$ to 0.3) across all cadence ranges (Δ: 1 to 4°).

Sex differences demonstrated a large effect for TQ_{peak}, P_{on}, and P_{max}, ($d=2.3$ to 3.2) and small effects for Ang_{left} and Ang_{right} ($d=.2$ to $.3$).

Table 1

(a)

Female athletes

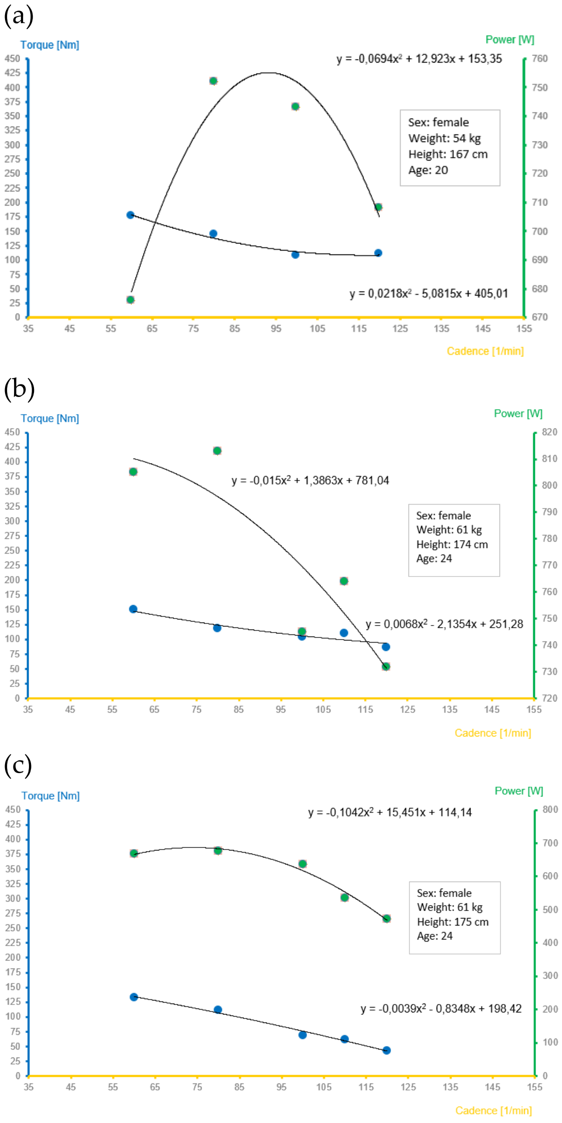
Cadence (rpm)	TQ_{peak} (Nm)	P_{on} (W)	P_{max} (W)	Ang_{left} (°)	Ang_{right} (°)
60	153±18	1104±111	716±63	115±2	116±3
80	126±14	1130±66	747±56	122±2	121±5
100	94±17	1031±148	708±51	117±9	112±15
110	86±25	905±177	650±114	124±3	112±10
120	80±28	909±220	638±117	124±2	114±13

(b)

Male athletes

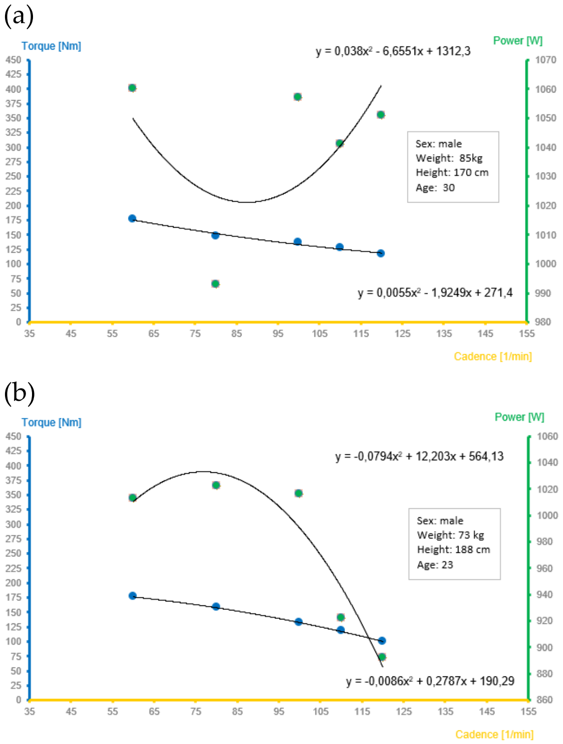
Cadence (rpm)	TQ_{peak} (Nm)	P_{on} (W)	P_{max} (W)	Ang_{left} (°)	Ang_{right} (°)
60	177±1	1510±1	1037±24	116±6	113±2
80	153±6	1554±12	1008±15	118±4	119±6
100	135±3	1536±43	1037±21	121±7	115±3
110	124±5	1502±65	982±160	122±4	121±4
120	108±8	1440±123	972±80	121±12	121±9

Figure 1



Figures 1 (a), (b) and (c) show the individual torque-power-velocity profile for each of the three female subjects. It becomes visible, that power output is very individual for different starting pedaling frequencies. Here, for example, it is a parabolic shape, almost linear or something in between. Regardless of the achieved peak torque, the values follow a nearly linear pattern for every female athlete.

Figure 2



Above shown figures 2 (a) and (b) display the torque-power-velocity profile for each of the two male participants. As with the women's data, the decrease in peak torque is linear with the initial cadence. Furthermore, the two curves of the one-second peak powers are parabolic. Thereby, in figure 2 (a) it is a parabola open at the top, in figure 2 (b) the parabola is open at the bottom. The results show that the peak torque is higher at a lower initial cadence, but the maximum power output varies at different initial cadence values.

4. Discussion and practical applications

The first important finding of the study is that torque in all subjects decreased nearly linear with an increase of initial cadence. However, the performance output does not follow a clear pattern and thus shows the high individuality of the sprint. Likewise, maximum achieved on power (Pon) with corresponding crank angle shows the real peak power in a crank revolution.

None of the participants did sprints regularly in training. Still, the individual weakness or strength for different starting cadences in sprints can be comprehended. Also, the best possible cadence can be calculated.

Second important finding of the study is that a torque-power-velocity profile now can be established without any additional equipment outside of a laboratory.

Nonetheless, further research should be conducted i.e., taking non-shifting, longer sprint durations or smaller steps in starting cadence into account. Also, investigations in track cycling can be an interesting field for a torque-power-velocity profile as track riders are limited to one gear only.

5. Conclusions

This present research has demonstrated a torque-power-velocity profile for cyclists and the uniqueness of cycling sprints in field for female and male athletes. With little equipment a good insight into sprinting ability of the subjects has been shown. These findings and the scientific studies carried out in the future with the used material could improve sprint performance in cycling. In addition, the understanding of power composition in sprints can be analyzed in more depth.

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