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The effect of aerodynamic characteristics on the drafting effect in track cycling

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Abstract

Introduction: Since the aim of the men's team pursuit is to accomplish a distance of 4000m as fast as possible, reducing aerodynamic drag by means of drafting can attribute in achieving this goal. Broker et al.[1] quantified the average effect of drafting on power requirements in a team pursuit based on practical experimental data. However, since team members are not identical and will differ in aerodynamic characteristics, expressed as frontal projected areas (Ap) and drag coefficients (Cd), the reduction in power is likely to vary among individuals. A prediction of the magnitude of the drafting effect based on aerodynamic characteristics of team members can result in a more specific estimation for required power per position than the model of Broker et al.[1] This study focuses on the effect of frontal area of team members on drag reduction, expressed as percentage of the drag coefficient measured in first position (drag fraction).

Methods: Eight experienced track cyclists of the Dutch national selection performed 39 trials of 3km in different teams of four cyclists at a constant velocity of 15.75 m/s. Subject characteristics are shown in table 1. Frontal projected areas were determined[2,3], shown in figure 1, and drag coefficients (Cd) for all four positions were calculated using a mathematical model for track cycling[4,5]. The relationships between frontal areas of team members and drag fractions were estimated using generalized estimation equations (GEE)[6].

Results: Average measured values are presented in table 2. Table 3 presents the results of the GEE for drag fraction in second, third and fourth position. For second position significant predictors were the frontal area of the drafter himself (Ap@2) ($p<0.01$) and, to a lesser extent, the Ap of the leader (Ap@1) ($p=0.05$). Furthermore, an interaction of Ap@1 and Ap@2 on drag fraction was found, illustrated in figure 2. For both third and fourth position the drag fraction is mostly determined by the Ap of both the cyclist directly in front of the drafter and drafter himself ($p<0.01$). Incorporating these outcomes in the used model, figure 3 shows the estimated required power per position at a velocity of 15.75 m/s plotted against the eight participating subjects in all three drafting positions. Required power is depicted as a range, where the variation in characteristics of the current selection of cyclists was used for determination the highest and lowest values corresponding with a worst and best team composition regarding the drafting effect.

Discussion: An effect of leader's aerodynamic characteristics on the drafting effect was also found by Edwards et al.[7] In the current study, in addition an effect of Ap of the cyclist in second position on drag fraction, as well as, an interaction effect between Ap in first and second position was found. This suggests that a small drafter benefits less than a large drafter when the leaders' Ap increases. So to speak, a larger drafter has 'more to gain' and 'more to lose'. Variation in drafting effect between different cyclists is demonstrated by Defraeye et al.[8] using Computational Fluid Dynamics (CFD). The current results focus on the range within drafting subjects, making clear that both between and within drafters the team composition may cause a considerable difference in drafting effect. At this velocity, ranges are minimal 15 W but can reach up to 35 W in second position for larger cyclists. Technical skills may have influenced the accuracy of outcomes, but all trials were checked for excessively poor execution of the trials. Moreover, the practical execution does contribute to the ecological validity of the results.

These estimated power requirements for each cyclist can be valuable for a coach to make decisions regarding cyclist selection and team composition. This, in combination with cyclists' potential capabilities, can give insight into the time to cover a men's 4k team pursuit.

Acknowledgement

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Table 1: Subjects' characteristics

Subject	Height (cm)	Bodyweigt + bike (kg)	Ap (m^2)*	Cd*	Ad (m^2) *	Power (W)*
1	177.5	84.6	0.336	0.545	0.183	441
2	186.0	81.7	0.339	0.565	0.192	459
3	178.5	86.5	0.345	0.572	0.197	485
4	184.5	79.5	0.361	0.569	0.205	488
5	185.0	88.5	0.374	0.557	0.208	496
6	186.0	90.0	0.382	0.593	0.226	536
7	192.0	90.8	0.401	0.583	0.234	574
8	199.0	97.9	0.411	0.576	0.236	578
Mean ± SD	186.1 (6.9)	87.4 (5.8)	0.369 (0.028)	0.570 (0.015)	0.210 (0.0120)	507 (51)

* Averaged value in first position during the trial

Table 2: Mean values ± SD for absolute power, relative power and drag fraction.

Position	Power (W)	Power as percentage of position 1 (%)	Drag fraction
1	507 (50.5)	100	
2	334 (37.2)	65.8 (1.6)	0.64 (0.017)
3	289 (36.7)	57.0 (1.7)	0.55 (0.019)
4	286 (37.7)	56.2 (2.0)	0.54 (0.019)

Table 3: Results of General Estimation Equations of factors that influenced the drag fraction in second, third and fourth position

	Parameter	B	SE (B)	Sig. (*p*)
Drag fraction @2	Intercept	0.098	0.2669	0.72
	Ap@1	1.295	0.6637	0.05
	Ap@2	2.103	0.7264	<0.01
	Ap@1*Ap@2	-5.228	1.7889	<0.01
Drag fraction @3	Intercept	0.583	0.0448	<0.01
	Ap@1	-0.105	0.0788	0.18
	Ap@2	-0.468	0.0764	<0.01
	Ap@3	0.470	0.0556	<0.01
Drag fraction @4	Intercept	0.530	0.0934	<0.01
	Ap@1	-0.085	0.0622	0.17
	Ap@2	-0.042	0.0706	0.56
	Ap@3	-0.434	0.0843	<0.01
	Ap@4	0.581	0.1424	<0.01

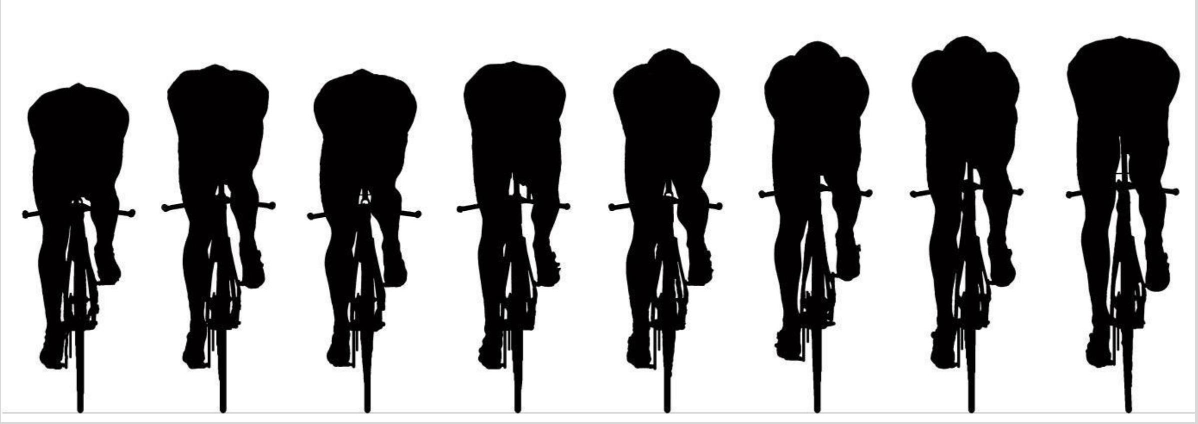

Figure 1. Projected frontal area All eight subjects in ascending order

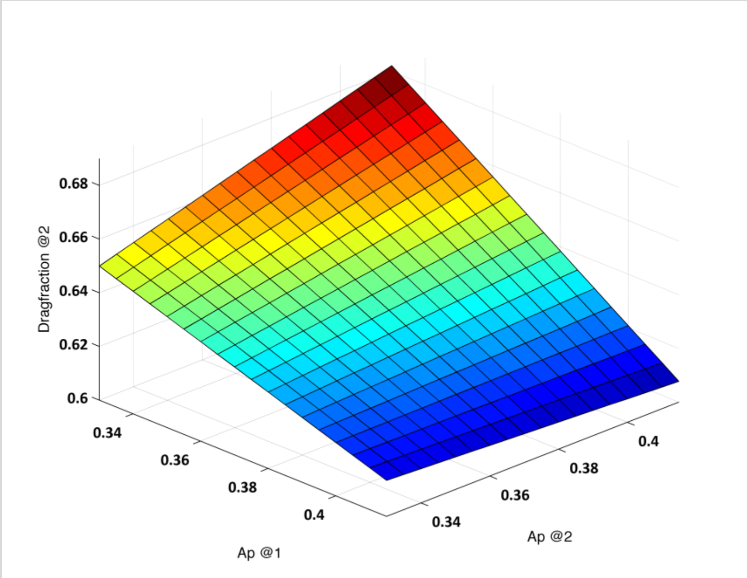

Figure 2. Interaction effect in second position The interaction effect of Ap@1 and Ap@2 on drag fraction in second position is illustrated by a three-dimensional presentation of the estimated equation. This figure indicates that a drafter with a low Ap benefits to a lesser extent than a drafter with a large Ap as the leader's frontal area increases.

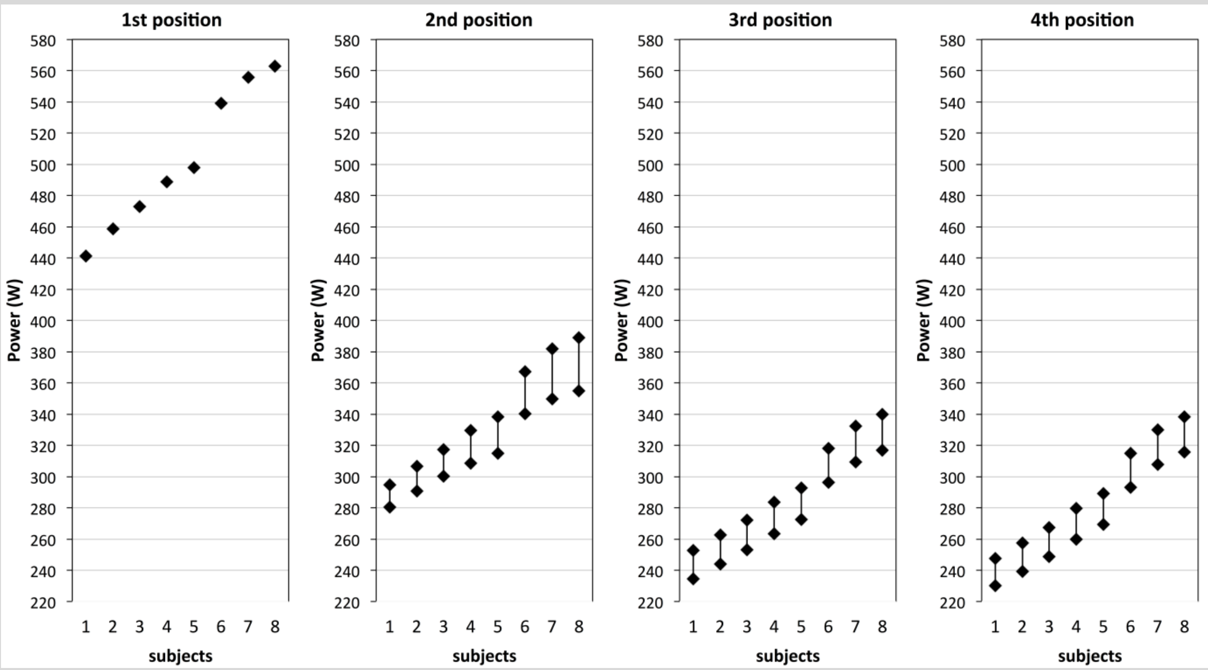

Figure 3. Power requirements per position Calculated range of power requirement per position plotted against each subject at a velocity of 15.75 m/s. The highest point of each range represents estimated required power in the 'worst' configuration of other team members regarding the drafting effect for the eight participating cyclists. The lowest point represents required power in the 'best' configuration.

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