# BENEFITS OF DRAFTING ON THE LEADING CYCLIST: A PRELIMINARY FIELD STUDY

Miguel Ángel Benito, Alba Herrero-Molleda and Juan García-López

Faculty of Physical Activity and Sport Sciences, Universidad de León, Spain

The effect of drafting on the aerodynamic drag of a trailing cyclist has been widely investigated. However, no experimental field study has quantified under field conditions the potential benefit of this strategy on the leading cyclist, which is the purpose of the present study. Therefore, a protocol based in a previous study performed in velodrome (García-López *et al.*, 2014) was designed. Results indicate that drafting decrease the leading cyclist's drag area (CdA) by 2.6 and 3.3%, and the trailing cyclist' CdA by 31.9 and 19.3%, depending on the trailing cyclist position on the bicycle (*i.e.*, aero *vs.* upright position, respectively). Although Rate of Perceived Exertion (RPE) values behaved similarly to CdA (*i.e.*, when CdA decreased RPE also decreased), quantitatively the RPE method was not sensitive enough to detect small changes in aerodynamic drag.

**KEYWORDS:** cycling, performance, aerodynamic drag, Rate of Perceived Exertion.

**INTRODUCTION:** During road cycling without drafting, aerodynamic drag represents more than 90% of the total resistive forces when the speed is higher than 40 $km \cdot h^{-1}$, depending on the equipment and posture used by the cyclists. Therefore, aerodynamic drag is highly relevant to road cycling performance, especially in time-trial stages (García-López *et al.*, 2014). In fact, in road cycling competitions is very usual to see cyclists trying to follow another cyclist (*i.e.*, drafting) in order to reduce their resistance and, thus, the power and energetic expenditure required. It has been estimated a benefit around 30% for a cyclist performing drafting behind another cyclist, depending on the wheel-to-wheel distance and the anthropometric characteristics of the leading cyclist (Edwards & Byrnes, 2007; Blocken *et al.*, 2013). However, this benefit can go up to 95% when the cyclist is accurately positioned in a peloton of 121 riders (Blocken *et al.*, 2018). In the last few years, some research have been focused on the effect that a trailing cyclist might have on the aerodynamic drag of a leading cyclist, using both wind tunnel (Iñiguez-de-la-Torre & Iñiguez, 2009) and Computational Fluid Dynamics -CFD- assessments (Blocken *et al.*, 2013). It has been estimated a benefit between 2.6 and 5.0% for the leading cyclist due to the influence of the trailing one, which has been justified because the trailing cyclist decreases the air pressure gradient between the front and the back of the leading cyclist. However, to the best of our knowledge no experimental field study carried out in a velodrome has verified these findings, even though velodrome tests have been proven reliable in detecting changes in the aerodynamic drag in cyclists (García-López *et al.*, 2014). In addition, although cyclists' Rate of Perceived Exertion (RPE) has been widely used in cycling for the last 25 years to monitor training load (Foster *et al.*, 2021), no previous aerodynamical study has quantify its sensitivity to detect changes in aerodynamic drag. Therefore, the main purpose of the present study was to test under field conditions the potential benefits of riding while having a trailing cyclist. The secondary aims were to assess the effect of the cyclist's position on the bicycle (*i.e.*, aero position *vs.* upright position) on these potential benefits and to compare the changes in aerodynamic drag with those in the cyclist's RPE.

**METHODS:** Seven male road cyclists and triathletes participated in the present study (age: 28.3 ± 9.1 yr, height: 177.2 ± 5.9 cm, body mass: 69.6 ± 6.9 kg, bicycle + body mass: 81.5 ± 6.1 kg, and saddle height measured from the ground: 101.6 ± 3.6 cm). They were club cyclists (Ansley & Cangley, 2009) with at least 6 years of cycling experience and 5.000 km cycled on the current year. All of them were informed of the procedures, methods, benefits and possible risks involved in the study, and written consent was obtained before starting it. The tests were performed in a one-day session on a 250 m indoor velodrome (122.15 m straight and 127.84 m curve), using the participants own bicycles and under controlled environmental conditions (Weather station PCE-FWS 20, PCE Ibérica S.L., Spain). All cyclists performed a 15 min warm-

up before the testing, consisting of 3 min of low intensity pedaling and 3 sets of 4 min pedaling at 35, 38 and 42 km·h$^{-1}$ while holding an aero position (*i.e.,* with the forearms on the aero bars). After a 5 min rest period, the cyclists performed 5 sets of 4 min of pedaling adopting five different positions (Original, Leader, Leader- Drafting and Drafting-) following the methodology described by García-López *et al.* (2014). All pedaling sets were performed in pairs (*i.e.,* a leading cyclist and a trailing cyclist), excepting the Original position, at a constant speed of 45 km·h$^{-1}$ and with 5 min rest in between. As previously stated, the first set of pedaling (Original) was performed individually, and the cyclists were asked to maintain an aero position. In sets 2 and 3 ("Leader" and "Drafting"), leading and trailing cyclists pedaled in-line maintaining an aero position. Sets 4 and 5 ("Leader-" y "Drafting-") were similar to the previous two, difference being that the trailing cyclist had to adopt an upright position (*i.e.*, with the hands on the brakes). The order of the sets (2 and 3, 4 and 5) was randomized in the two cyclists, and they were requested to ride with a wheel-to-wheel distance between 0.50 and 1 m.
During each set of pedaling, power output, bicycle speed and cadence were recorded with a power meter (Powertap G3-Disc Hub Powermeter, Sram LLC, EE.UU.) and a speed sensor (ANT$^+$/Bluethoot Smart, Garmin International, Inc, EE.UU.) that were placed on the rear wheel of the bicycle. The RPE was monitored during the 5 min recovery interval between sets by using Borg's original scale (6-20) (Rodríguez-Marroyo *et al.*, 2012). Lastly, the drag area (CdA) and the drag area to body mass ratio (CdA·kg$^{-1}$) were calculated, as defined in García-López *et al.* (2014), from pedaling power, efficiency of the drive system (97.7 %), changes in potential and kinetic energies, bicycle speed and a global coefficient of friction, which included rolling resistance and wheel-bearing friction. Non-parametric Friedman ANOVA test was used to analyze the effect of the cyclist's position (*i.e.*, Original, Leader, Leader-, Drafting and Drafting-) on both CdA and RPE, using the Wilcoxon paired test to analyze individual differences between two positions. The statistical significance level was set at $p < 0.05$.

**RESULTS:** Overall, the position of the cyclist (*i.e.*, Original, Leader, Leader-, Drafting and Drafting-) affected both CdA (chi-square = 27.6 and p = .0001) and RPE (chi-square = 26.5 and p = 0.0003). In the Original position, the CdA was 0.270 ± 0.020 m$^2$ and the CdA·kg$^{-1}$ was 3.73 ± 0.02·10$^{-3}$ m$^2$/kg. Figure 1 shows a significant decrease ($p < 0.05$) of CdA in the Leader, Leader-, Drafting and Drafting- positions (2.6, 3.3, 31.9 and 19.3%, respectively) with respect to the Original one, and significant differences in-between. For RPE the percentages of these differences were higher (6.9, 12.3, 36.2 and 22.3%, respectively), but no significant differences ($p < 0.05$) were observed between Original *vs.* Leader and Leader *vs.* Leader- positions.

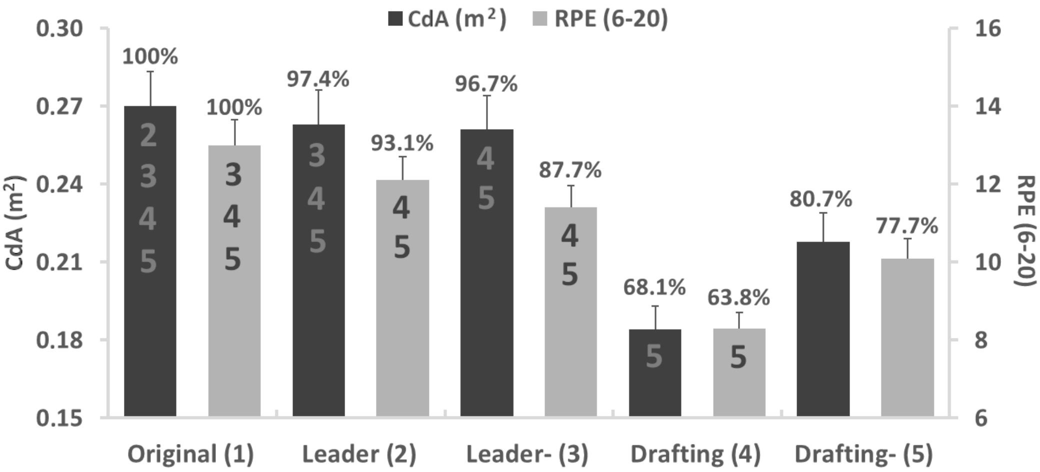


**Figure 1: drag area (CdA) and Rate of Perceived Exertion (RPE) registered in the 5 sets of pedaling. Original (1) = the cyclist pedaled individually holding an aero position; Leader (2) and Drafting (4) = the leading and trailing cyclists pedaled in-line holding an aero position, respectively; Leader- (3) and Drafting- (5) = the leading cyclist pedaled holding an aero position and the trailing cyclist holding an upright position, respectively. Percentage values with respect to the Original position. 1, 2, 3, 4, and 5: Significant differences with respect to the Original, Leader, Leader-, Drafting and Drafting- positions, respectively.**

**DISCUSSION:** The primary outcome of this study was to demonstrate under field conditions that riding while having a trailing cyclist has a reduction in CdA between 2.6 and 3.3%. These values are similar to those obtained in previous studies carried out using CFD simulations (*i.e.*, 2.6%), but it should be noted that these studies omitted details such as the inclusion of the bicycle in the simulation (Blocken *et al.*, 2013). However, both results are lower than those obtained in the wind tunnel, where the reduction in aerodynamic drag ranged between 4.0 and 5.0% (Iñiguez-de-la-Torre & Iñiguez, 2009). These differences may be due to the fact that the wind tunnel studies did not consider lateral deviations, rolls, and small movements of the cyclists (García-López *et al.*, 2008), as well as variations in the wheel-to-wheel distance through the test. In addition, this benefit is greater when the trailing cyclist maintains an upright position, possibly because it increases the air pressure gradient between the front and back of the leading cyclist, as has been described when riders are followed by motorcycles or cars (Blocken *et al.*, 2016).

The decrease in CdA observed in the Drafting position (31.9%) is in accordance with previous studies that observed between 27 and 33% of decrease in the aerodynamic drag (Edwards & Byrnes, 2007; Blocken *et al.*, 2013), thus this benefit is approximately 10 times greater than that observed in the leading cyclist (31.9 *vs.* 2.6-3.3%, respectively). However, this decrease was smaller (19.3%) when the drafting position was not optimal (*i.e.*, upright with the hands on the brakes), probably because the difference in the air pressure gradient between the front and back of the trailing cyclist increases with an upright position (Blocken *et al.*, 2013). Therefore, from both qualitative and practical perspectives, the position of the trailing cyclist has more effect on himself than on the leading cyclist.

Figure 1 shows that RPE values behaved similarly to CdA from a qualitative point of view (*i.e.*, when CdA decreased RPE also decreased). But quantitatively, this is not the case, because the changes observed in the RPE are more pronounced than those described for the CdA, and even in some positions no significant differences were obtained (*e.g.*, Original *vs.* Leader and Leader *vs.* Leader-). Although RPE has been widely used in cycling to monitor training load (Foster *et al.*, 2021), it is possible that this methodology overestimates the effects different positions might have on aerodynamic drag. Likewise, this scale is sensible enough to detect changes in training intensity, but not small changes in the aerodynamic drag of cyclists. Therefore, future studies should verify these findings using a larger number of cyclists familiarized with the scale.

Finally, the mean values obtained for CdA and CdA·$kg^{-1}$ on the Original position at 45 km·$h^{-1}$ (0.270 ± 0.20 $m^2$ and 3.73 ± 0.02·$10^{-3}$ $m^2$/kg, respectively) are clearly higher than those referred in previous studies performed at the same speed on elite cyclists (0.237 ± 0.16 $m^2$ and 3.47 ± 0.02·$10^{-3}$ $m^2$/kg, respectively) (García-López *et al.,* 2014). One possible explanation could be that the cyclists who participated in the present study were club cyclists and, therefore, did not have the necessary technical skills to be efficient on time-trial bicycles. Hence, future studies should check whether the competitive level of the drafting cyclist could have an effect on the benefits of the leading cyclist.

The main limitation of the present study was the low number of cyclists evaluated (n= 7), which was due to the travel restrictions implemented during the COVID-19 pandemic period, which made it difficult to access data of competitive cyclists. Likewise, even though most of the cyclists were used to using RPE (0-10) scales during training, no specific period of familiarization with the scale used in this study (6-20) was carried out.

**CONCLUSION:** In field conditions, during drafting in pairs with aero-bikes, the trailing cyclist decreases between 2.6 and 3.3% the drag area of the leading cyclist, depending on the position of the trailing cyclist (*i.e.*, aero or upright position). The benefit of the leading cyclist is about 10 times lower than that observed in the trailing one, and the position of the trailing cyclist has more effect on himself than on the leading one. These benefits can also be observed in the cyclist's Rate of Perceived Exertion, although it seems overestimated, and is not sensitive enough to detect small changes in aerodynamic drag. Further studies with a larger number of participants who are familiarized with the (6-20) RPE scale are necessary.

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