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Conference Abstract

Reliability and Sensitivity of the Notio Device and Aeroscale Service to Quantify Cyclists' Drag Coefficients in Outdoor Conditions

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Abstract: Notio is a device based on a wind sensor which offers estimates of the C_dA (drag coefficient multiplied by the area) of the pair cyclist and bike. Notio is used with a specific analysis software, which computes C_dA estimates after a ride. The Aeroscale Company proposes a half-day service with their own wind sensor and experimental protocol, to also deliver estimates of the C_dA. In both cases, the main objective of a wind sensor is to give estimates in outdoor conditions. The aeroscale specificity is that all experiments are done without any power sensor, in freewheel. In our study, we experimented Notio device and software as well as Aeroscale Service through an incremental protocol with increasing disks, which led us to obtain sensitivity measure precisions of 4.8% for Notio and 0.5% for Aeroscale, with good reliabilities (ICC=0.98 for Notio and 0.93 for Aeroscale).

Keywords: Aerodynamic drag coefficient, outside experimental protocols, cycling mechanical power, cycling tires rolling resistance, real performance conditions, embedded sensors and software intensive devices

1. Introduction

At 50 km/h, on a flat road and no wind, more than 90 % of resistance forces against the cyclist and his/her bike come from aerodynamic resistance, characterized by the horizontal drag coefficient (*Cd*) multiplied by the frontal area (*A*). Devices aimed at estimating the *CdA* of a cyclist in outdoor environments have recently been marketed. The aim of our study was to measure the *reliability* and the *sensitivity* of two out of these devices and their associated experimental protocols: the Canadian Notio (Argon 18®), and the French Aeroscale.

2. Materials and Methods

By *reliability*, we mean the proximity of the results under very similar conditions, whereas *sensitivity* captures the ability to measure or not small variations of the experimental conditions.

Concerning Notio, we had two different Notio devices (only one per bike), used with Garmin 1000 and 1030 bike computers equipped with speed, cadence and power meter sensor (Power2max crankset + Assioma uno pedals). Three different series of five runs were monitored. A run consisted of a round trip on the same segment, on a cycling road along a canal: 3 km long, flat, straight, regular surface, pure head wind or tail wind that speed is less than 10 km/h, no side trees, no houses or cars, no other person on the segment. Speed, cadence, and position should be as constant as possible (30 km/h, 85 rpm), as well as the total mass. Temperature, air-pressure, air speed, accelerations, were all measured by the Notio device. Notio results were analyzed via GC Notio, *i.e.* the free analysis platform Golden Cheetah with a specific add-on. We also computed the datas with our own algorithms (Notio GC algorithms are black boxes) to see if we had similar results. For this purpose, we considered Martin's usual bike power equations from which we can deduce *CdA* once we know wind speed and air density, having also an estimation of tires rolling resistance and transmission and bike yields.

The first series was carried out without any aerodynamic brake, the second one with disks of diameter 12 cm, and the third one with disks of diameter 15 cm. The disks were fixed at 45 cm from the left and right sides of the handlebars. This led us to perform more than 150 km of experiments to keep 90 km (3x5 final selected runs) to analyze. The experiments, both for Notio and Aeroscale, were performed by two cyclists (52 years old, 188cm, 78kg, regular cyclist, 23 years old, 172cm, 69kg, unregular cyclist) and two bikes, and all the experiments we used to compute reliability and sensitivity concern the same cyclist (the young one) and same bike.

Concerning Aeroscale, we performed experiments under the supervision of an expert of Aeroscale Company, for half a day. The only devices used were the Aeroscale ones, without any need for an external sensor (in particular *no power meter*): the Aeroscale device measured bicycle speed, air speed, temperature etc. Note that speed sensors communicating via ANT+ protocol are excluded, since communication delay is about 1 s via this protocol. Runs were on two segments of 300m and 400m long, for which we precisely knew declivity (precision better than 1cm for length and declivity). Like for Notio, we did round-trips, but the cyclist was only pedaling in freewheel, therefore at a low cadence (60 rpm). Speed was also obviously not constant. In addition, the outside temperature of all experiments must not vary by more than 5°C. Additionally, Aeroscale also offers a second experimental protocol (not described here) for estimating tires rolling resistance.

With Aeroscale also, we kept 3 series of 5 runs: without any disk, with 12 cm disks, and with 15 cm disks. The Aeroscale staff computed the results.

3. Results

Our experiments on both devices with associated protocols have a good reliability, defined here by the reproducibility: ICC = 0.98 for Notio and ICC = 0.92 for Aeroscale.

However, we measured a poor sensitivity of the Notio device. The theoretical increase of *CdA* with large discs should be 0.037 m². Notio found an increase of 0.058 ± 0.009 m², *i.e.* a whole *CdA* difference between practical and theoretical of 4.8 %. Aeroscale found an increase of 0.035 ± 0.003 m², *i.e.* a precision of 0.5 %. Concerning small discs, Aeroscale precision is also around 0.5 %.

Besides, Aeroscale measured tires rolling resistance of two pairs of tires at 0.31% and 0.45%, respectively for continental GP5000 in 25mm and Vittoria Rubino 23mm. These values are consistent with published ones (bicyclerollingresistance.com).

4. Discussion

Concerning Notio, the independent study [1] obtained a whole sensitivity of 1.2% with a good reliability. They follow a very similar protocol, but in an indoor velodrome, with elite riders at much higher speeds (50 km/h). We can also compare these indoor results with classical protocols without any wind sensor, whose sensitivity is also about 1%. We may wonder whether a wind sensor is useful indoor. Outdoor study [2] leads to a good reliability and a sensitivity of 4.2%.

We did not find other results with precisely these two devices. The Aeroscale Company is the only one who did precise experiments with their devices. Until now, Aeroscale had not done such a sensitivity analysis with growing disks.

All these results can be compared with indoor experimental results obtained by a method described in [3], which is a good method in indoor ideal conditions, but at the cost of 15 runs.

Concerning long outdoor rides, even if Notio officially claims to offer real-time results (with a Garmin data field), we state that: i) real-time displayed *CdA* is still utopic, since it always varies between 0.1 and 0.7 m^2, even on apparently constant conditions; ii) post analysis after a typical 50 km ride on various roads won't detect any *CdA* changes less than 15%, and reliability won't be better than 30%. We have to use such wind sensor devices, as Aeroscale does, in very controlled outdoor conditions. Without any power sensor, Aeroscale results are well better, but Aeroscale is not able to measure how a cyclist would deteriorate his *CdA* by pedaling hard, for example, since is makes all measures while coasting.

5. Practical Applications.

Pro Cyclists teams obviously look for all legal aerodynamic improvements and knowledge. Outside ***CdA*** estimations are attractive since they can be done on portions of athletes usual training roads and give results which are intrinsically more robust. For amateurs, it makes even more sense since no "Sunday-rider" will have the opportunity to do wind-tunnel sessions. It appears that even at lower speeds (*e.g.* 30 km/h), improving ***CdA*** leads to save many Watts. And "Sunday-riders" also look for comfort: such tests can only be done during long outside sessions.

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