23. The Power of Eliud Kipchoge

The spectacular performance of Eliud Kipchoge at the Breaking-2 attempt has inspired many runners and writers. He came mighty close to the 2-hour barrier with his finishing time of 2:00:25 for the marathon at the Monza racing track. We have seen many papers and blogs speculating on the potential impact of the special Nike shoes, the special Maurten sports drink and the drafting by the pacer car and pacing groups. Most authors believed that the biggest gain was due to the drafting: the Tesla car with the big electronic screen acted as a giant wind break and the pacers ran in an aerodynamically optimized configuration. In this paper we will analyze the unbelievable performance of Eliud, using the theory and the running model from our book (www.thesecretofrunning.com). We will derive the Wattage that Eliud maintained during the race and we will show that the drafting was indeed near perfect.

How high was the Wattage of Eliud during the attempt?

As far as we know, the Wattage of Eliud during the attempt was not measured. This is most unfortunate, as Stryd-data could have provided interesting information on the limits of human performance. However, as we have shown in our book, we can estimate the limits of human power quite accurately from the world records in athletics. We have calculated the Functional Threshold Power (in Watt/kg, this is the power that can be maintained for 1 hour), which is equivalent to each of the present world records between 3000 meter and the marathon . The results are shown in the table below:

World records men			FTP
Distance	Time	Name	(Watt/kg)
3000 m	7:20.67	Daniel Komen	6.32
5000 m	12:37.35	Kenenisa Bekele	6.33
10,000 m	26:17.53	Kenenisa Bekele	6.36
15 km	00:41:13	Leonard Komon	6.24
20 km	00:55:21	Zersenay Tadese	6.32
21.1 km	00:58:23	Zersenay Tadese	6.34
25 km	01:11:18	Dennis Kimetto	6.22
30 km	01:27:38	Emmanuel Mutai	6.14
42.2 km	02:02:57	Dennis Kimetto	6.30

The table shows that the (equivalent) FTP of most world records is quite comparable, in particular when we neglect the records at 15, 25 and 30 km as these distances are run less frequently. From the table we conclude the limit of human power in running is around 6.35 Watt/kg. In our book we have shown that this value is confirmed by data from other endurance sports such as cycling.

So, let us assume that Eliud Kipchoge ran at this limit of human power, i.e. at an equivalent FTP of 6.35 Watt/kg. As his body weight is 57 kg, this means a total FTP of 6.35*57= 362 Watt. Of course, we still have to correct for the power-time relationship. As he ran for 2 hours, he could maintain:

$P = 2^{-0.07} * FTP = 345$ Watt

Consequently, we conclude that Eliud probably was able to run at a power of 345 Watt during the 2 hours of the Breaking-2 attempt. As he ran at a speed of 5.84 m/s, we can also calculate that his total Energy Cost of Running (ECOR) was 6.35/5.84= 1.087 kJ/kg/km. Please note that we have calculated the ECOR as follows:

ECOR (in kJ/kg/km) = Specific Power (in Watt/kg) divided by the speed (in m/s)

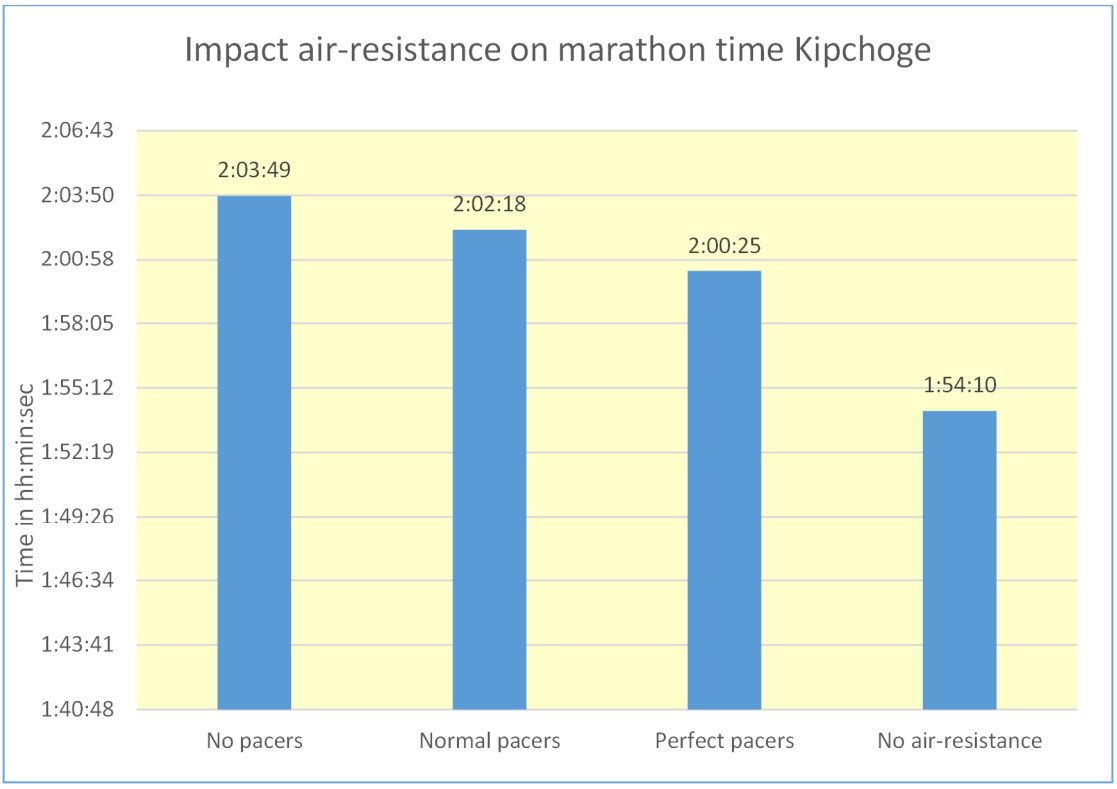
How big was the impact of the air-resistance?

In our book we have shown that runners always need additional power to surmount the air-resistance. The amount can be calculated by the following formulae:

$P_a=0.5\rho c_d A v^3$

The breaking-2 attempt was run at a temperature of 12 °C, which means that the air-density ρ was 1.239 kg/m^3. In our book we have shown that without pacers the air-resistance coefficient c_dA is equal to 0.24 m^2. As Eliud ran at a speed v of 5.84 m/s, this means that without pacers he would have needed 0.5*1.239*0.24*5.84^3= 29.6 Watt to overcome the air-resistance. This is some 29.6/345= 8.5% of his available power of 345 Watt. So, it is clear that the air-resistance really does have a significant impact on the performance.

Obviously, most world records are run with the aid of pacers. In our book we have concluded that the drafting effect of pace makers usually leads to a reduction in the air-resistance coefficient to 0.20 m^2. So, the big question is how big the drafting effect of the aerodynamically optimized Tesla car/wind screen/pacer groups has been? We have calculated that with our running model, which enables us to calculate the marathon time for various air-resistance values. The results for the race of Eliud Kipchoge are given in the graph below:



The graph shows the following:

- If Eliud had run alone (so without pacers) under the same (near-ideal) conditions, he would have needed 2:03:49 for the marathon
- If Eliud had run with 'normal pacers' (i.e. a group of 3 pacers for around 25-30 km), he would have finished the marathon in 2:02:18 (so still an impressive improvement of the existing world record of Dennis Kimetto)
- The (near) perfect pacing realized during the attempt resulted in a time of 2:00:24. From our calculations we conclude that this is equivalent to a c_dA-value 0.15 m^2. This is really a very

low value that we have not seen before, so the drafting was really near-perfect. We note that it means that the air-resistance was reduced by 37.5% or 11 Watt. This is quite impressive, especially when we realize that the drafting impact of a full cycling peloton is some 40%.

- If Eliud had run without any air-resistance (e.g. on a treadmill) he could theoretically have finished the marathon in 1:54:10. However, this would have been a very boring marathon…

Discussion and conclusions

Of course, there are still a number of buts… First, this is just theory, as we do not have the real-time power and aerodynamical data of Eliud. Second, we have neglected that impact of the shoes and nutrition. If these really helped significantly, we should conclude that the impact of the drafting may have been less big. However, all in all the numbers seems quite convincing to us and they confirm the importance of the air-resistance, also in running. In cycling and speed-skating, this is well recognized and aerodynamical optimizations are constantly being developed. We believe that one of the main results of the Breaking-2 attempt has been to show to the world that aerodynamics matter also in running!

We are curious to the reactions and experiences of the readers, we welcome you to share these at www.thesecretofrunning.com**.**

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The Secret of Running
Maximum Performance Gains Through
Effective Power Metering and Training Analysis

Publication Date: May 1, 2017
ISBNs: 9781782551096
9781782554363 (e-book, E-pub)
9781782557739 (e-book, PDF)
e-books are available on Stryd.com from January 19, 2017