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ADDENDUM

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Addendum

Why did Usain Bolt lose the 100 m sprint at London 2017?: addendum to 'Impact of mass gain, tailwind and age in the performance of Usain Bolt from Beijing 2008 to Rio 2016'

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Abstract

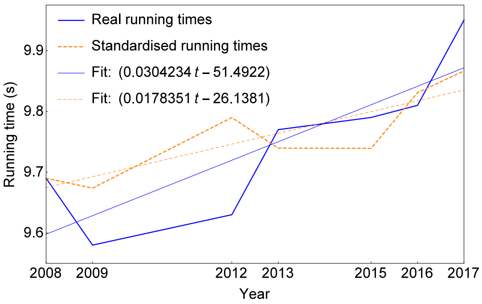
The unexpected bronze medal of Usain Bolt in the 100 m final sprint at London 2017 is of great interest from the physical point of view. In Hernández-Gómez *et al* (2017 *Eur. J. Phys.* **38** 054001), we applied our successful analytic mechanical model (Hernández-Gómez *et al* 2013 *Eur. J. Phys*. **34** 1227) to trace Usain Bolt from Beijing 2008 to Rio 2016 in order to assess the impact of the runner's mass, tailwind and even age in the performance of his 100 m sprints. In this paper, we extend the analysis by Hernández-Gómez *et al* (2017 *Eur. J. Phys.* **38** 054001) to consider the London 2017 100 m final sprint, so as to find the facts that made Usain Bolt actually lose the first place.

Keywords: Usain Bolt, mechanical model, hydrodynamic drag, sport physics, 100 metre sprint, world record, London 2017

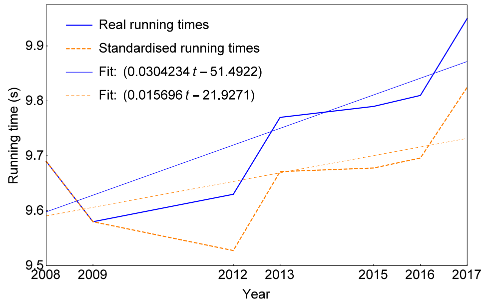
(Some figures may appear in colour only in the online journal)

1. Introduction

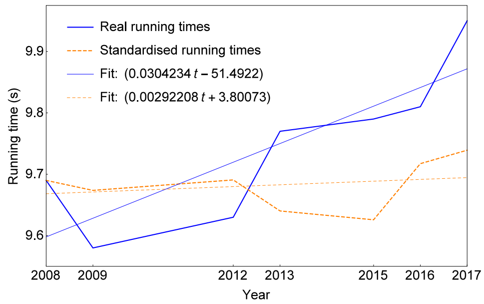
August 5th, 2017, surprised the world with Usain Bolt (UB) gaining just the bronze medal in the last 100 m sprint of his career at the London 2017 IAAF World Championships (WC).



(a) Wind standardised case.



(b) Mass standardised case.



(c) Wind and mass standardised case.

Figure 1. Real (blue, solid) versus standardised (orange, dashed) running times of Usain Bolt from Beijing 2008 to London 2017, for the three hypothetical cases. For comparison purposes, the reported times include their respective reaction times.

Of course, beyond the social relevance of this fact, the apparent downfall of UB in his try-out *par excellance*—the 100 m sprint—deserves a closer analysis of the physical variables that directly affected Bolt's performance in this particular event.

In Hernández-Gómez *et al* (2017) we applied the successful analytic mechanical model by Hernández-Gómez *et al* (2013) for the 100 m sprint in order to understand the performance of UB from Beijing 2008 to Rio 2016, focusing in the study on the relevance of parameters such as the mass and age of the runner, as well as the sprint tailwind. One of our key findings in the study was that UB's mass increment has been a determining factor for the apparent downfall in running times, aided in some cases by the tailwind at particular events. Moreover, with respect to the running times in standardised wind and mass conditions, we posed the question of whether the differences in standardised running times between different events may be considered as fluctuations from the almost constant running time shown by the data fit featured in figure 5 (of the aforementioned reference), or not. In this paper, with the results of UB in the 100 m sprint at London 2017, we are now able to state more conclusively about the role of age through the professional trajectory of the most impressive 100 m sprinter of the modern era. This paper is organised as follows. In section 2 we apply the referred theoretical model to the London 2017 WC, comparing this performance with the ones he displayed from Beijing 2008 up to London 2017, to get an insight into the change of physical variables such as force and power exerted by him in London 2017 with respect to these previous events. In section 3 we again simulate the events comprising the aforementioned timespan in three different hypothetical setups: if all had been run with the same tailwind conditions; if all had been run with the same UB mass; and if all had been run with the same mass and tailwind

Table 1. Values of the physical parameters F_0, γ and σ for both Berlin 2009 and London 2017.

Constant	Berlin 2009	London 2017	Percent difference (%)
F_0 (N)	815.8	802.4	−1.64
γ (kg s^{-1})	59.7	59.7	NA
σ (kg m^{-1})	0.60	0.68	13.91

conditions. Finally, in section 4 we pose some interesting concluding remarks about the role of mass and age in the career of 'Lightning Bolt'.

2. Usain Bolt's performance through the years

For the London 2017 IAAF WC, UB's mass was $m = 95$ kg (Eurosport 2017), which is 10.47% higher than the mass of 86 kg he had when he broke the world record at Berlin 2009 (Helene and Yamashita 2010, Hernández-Gómez *et al* 2013), and 1.06% greater than his mass in the previous Rio 2016 event (Hernández-Gómez *et al* 2017). Taking into account $m = 95$ kg as well as London 2017 conditions (altitude of 35 masl, humidity of 49% and temperature of 19 C), $t_s = 9.95$ s and $t_r = 0.183$ s (see table 2) (IAAF World Championships London 2017), we obtain the physical parameters of the model for UB's 100 m sprint at London 2017, which are shown in table 1, where we also present the corresponding values at Berlin 2009 (Hernández-Gómez *et al* 2013) for comparison purposes. Eight years after Berlin (2009), the force exerted by UB has reduced 1.64% while σ has increased almost 14%, mainly due to the particularly high negative tailwind in London 2017 (Hernández-Gómez *et al* 2013).

The progression of UB's key facts between 2008 and 2017 is shown in table 2; we notice that his mass at London 2017 is the highest of all times. For instance, at London 2017, UB was just about +0.03 seconds above Justin Gatlin (gold medal). This difference could be due to the particularly high reaction time of UB of 0.183 s, which is about 0.025 s greater than the average of his reaction times from Beijing 2008 to Rio 2016. It is also relevant to notice that at London 2017, UB faces the worst negative tailwind (−0.8 m/s) between all events herein studied.

UB's overall performace evolution from Beijing 2008 to London 2017 can be observed in table 3. At a first glance, it seems that London 2017's physical specs reverse the main tendencies shown in the previous years. For instance, the force exerted by UB (table 3, column 2) at London 2017 increased from Rio 2016 by 0.21%. Nevertheless, at Rio 2016, F_0 was 86.92% of his weight at such an event, while for London 2017 it was 86.10%, which is still lower. Thus, the greater exerted force (F_0) in London 2017 with respect to Rio 2016 is just because he is moving a greater mass. In table 3, column 3, we feature the terminal speed that UB could achieve, which at London 2017 is dramatically lower than in his previous 100 m sprints. This is mainly due to the combination of the lower exerted force and the most negative tailwind of −0.8 m/s. In table 3, column 4, we can observe that the initial acceleration of UB reduces from 0.87g at Rio 2016 to 0.86g at London 2017, which is consistent with the 1 kg of mass he gained in this timespan. Table 3, column 5 reveals that the maximum power for London 2017 was the lowest of all his events, despite the greater exerted force there than at Rio 2016, for instance, which is explained by the highly negative tailwind at London 2017. On the other hand, although the total work spent by UB at London 2017 was greater

Table 2. Key facts of Usain Bolt 100 m final sprints at Berlin 2009, London 2012, Moscow 2013, Beijing 2015, Rio 2016 (Hernández-Gómez *et al* 2017) and London 2017 (IAAF World Championships London 2017).

Event	Bolt's mass m (kg)	Official time t_s (s)	Reaction time t_r (s)	Wind speed v_w (m/s)	Temperature (C)	Humidity (%)	Altitude (m.a.s.l.)
Beijing 2008	86	9.69	0.165	0.0	21	71	43
Berlin 2009	86	9.58	0.142	+0.9	26	39	34
London 2012	93	9.63	0.165	+1.5	17	73	35
Moscow 2013	93	9.77	0.163	−0.3	21	62	156
Beijing 2015	94	9.79	0.159	−0.5	22	78	43
Rio 2016	94	9.81	0.155	+0.2	23	53	11
London 2017	95	9.95	0.183	−0.8	19	49	35

Table 3. Overall performance of Usain Bolt from Beijing 2008 to London 2017.

Event	Exerted force F_0 (N)	Terminal speed v_T (m/s)	Initial acceleration a_0 (m/s^2)	Maximum power P_{max} (W)	Total work W (kJ)	Effective work W_{eff} (kJ)
Beijing 2008	804.7	12.04	9.36	2554.35	80.465	6.235
Berlin 2009	815.8	12.16	9.50	2619.50	81.580	6.360
London 2012	805.7	12.35	8.66	2594.96	80.570	7.078
Moscow 2013	808.9	12.06	8.70	2575.38	80.890	6.755
Beijing 2015	810.6	12.03	8.62	2579.88	81.057	6.798
Rio 2016	800.7	12.03	8.52	2534.73	80.070	6.795
London 2017	802.4	11.84	8.44	2519.91	80.240	6.657

Table 4. Hypothetical running times of UB from Beijing 2008 to London 2017, calculated with the same tailwind conditions ($v_w^{(S)} = 0$ m/s).

Event	Original wind speed $v_w^{(O)}$ (m/s)	Standardised wind speed $v_w^{(S)}$ (m/s)	Original running time t_O (s)	Standardised running time t_S (s)	$t_O - t_S$ (s)
Beijing 2008	0.00	0.00	9.69	9.69	0.00
Berlin 2009	0.90	0.00	9.58	9.67	−0.09
London 2012	1.50	0.00	9.63	9.79	0.16
Moscow 2013	−0.30	0.00	9.77	9.74	+0.03
Beijing 2015	−0.50	0.00	9.79	9.74	+0.05
Rio 2016	0.20	0.00	9.81	9.83	−0.02
London 2017	−0.80	0.00	9.95	9.87	0.08

than at Rio 2016, this is simply explained due to the greater exerted force. Nevertheless, the effective work is lower at London 2017 than at Rio 2016, mainly because of his increment in mass as well as the negative tailwind of this particular event.

Now, comparing Berlin 2009 and London 2017, the terminal speed to which UB is subject changed −2.63%. Also, his initial acceleration decreased −11.16%, from 0.97g to only 0.86g, which is consistent with the ∼10.47% increment of his mass. The maximum power changed −3.80% and was reached at $t_{\text{Pmax}} = 0.89$ s and at $t_{\text{Pmax}} = 0.98$ s in 2009 and 2017, respectively. Further, the mechanical work exerted by UB reduced −1.64%, while the effective work increased +4.67%, which is due to the lower speed achieved in London 2017 with respect to Berlin 2009, which in turn decreases the value of the drag terms (that depend on v and v^2), dissipating less energy. Thus, the invested energy to achieve motion increased from 7.79% (of the total work) in 2009 to 8.29% (*idem*) in 2017.

In the following section we include London 2017 in the analysis by Hernández-Gómez *et al* (2017). We again consider three hypothetical cases, as if all events have occurred with the same tailwind, mass, and mass and tailwind conditions.

3. Hypothetical Usain Bolt's performance through the years: equating running conditions

3.1. 2008–2017: Without tailwind

In this case, we recalculate the physical variables of UB from Beijing 2008 to London 2017 considering a standardised tailwind condition of $v_w^{(s)} = 0$. In figure 1(a) we show the running times in both the real and hypothetical cases, where we can observe that, with respect to figure 3 of Hernández-Gómez *et al* (2017), the inclusion of London 2017 with no tailwind has increased the slope of the fit (orange, dashed) for the standardised values with no tailwind, from 0.0148563 to 0.0178351. The latter fact is due to the increase of mass of UB at London 2017. We also condense the running time results in table 4 for the tailwind-free case.

3.2. 2008–2017: With the same mass

In this case, we recalculate the physical specs of UB from Beijing 2008 to London 2017 considering a standardised mass condition of $m^{(S)} = 86$ kg. We assume that his ability to exert force does not change with his mass (Hernández-Gómez *et al* 2017). In figure 1(b) we show the running times in both the real and hypothetical cases. The difference between it and figure 4 of Hernández-Gómez *et al* (2017) is substantial, as in the latter, the fit of the wind-standardised case is essentially constant while in this paper such a fit acquires a positive slope, which is most likely associated with the most negative tailwind of London 2017. Table 5 shows the results of this case.

3.3. 2008–2017: Without tailwind and with the same mass

We recalculate the physical variables of UB from Beijing 2008 to London 2017 considering the same standardised wind conditions $v_w^{(S)} = 0$ m/s and mass $m^{(S)} = 86$ kg. We assume that his ability to exert force does not change with his mass (Hernández-Gómez *et al* 2017). Figure 1(c) shows the running times in the real and hypothetical cases. In table 6 we feature the results of this hypothetical case. The reported standardised running times contemplate the real reaction times of UB (see table 2)[3]. Thus, we support the conclusion of Hernández-Gómez *et al* (2017), that under standardised mass and tailwind conditions, the world record would have been established in Beijing 2015 with a running time of 9.63 s, confirming that, in real terms, the best performance of UB was in 2015. Surprisingly, notwithstanding the 9.95 mark of UB at London 2017, the main tendency of the wind- and mass-standardised results featured in figure 1(c) does not change substantially from the one presented in figure 5 of Hernández-Gómez *et al* (2017): from a slope of the standardised fit at such a reference of -0.00132279, it slightly changed to 0.00292208. So with respect to the question of the impact of age on the performance of UB, we can confirm the conclusion of Hernández-Gómez *et al* (2017), that UB is a stable athlete with respect to his performance as a 100 m sprinter. Actually, his running time has remained essentially constant (see figure 1(c)) through his entire sporting career. With such an almost-zero slope, UB's performance has been just slightly affected by his age from his world record breaking 100 m sprint in Berlin 2009 up to his farewell 100 m sprint at the London 2017 WC.

4. Conclusions

In this addendum we completed the analysis of UB's performance by Hernández-Gómez *et al* (2017) considering his entire sporting trajectory. For instance, a careful calculation shows that if he would have remained with $m = 94$ kg (as at Rio 2016), he would have obtained a silver medal with a running time of 9.936 s; actually, with $m = 94$ kg and a lower reaction time, he would have won the gold at London 2017. With respect to running times in standardised wind and mass conditions, the differences in standardised running times between different events may be considered as fluctuations from the almost constant running time trend shown by the fit in figure 1(c), which would be influenced by diverse, and mainly non-physical, factors. Also, the point-by-point results of figure 1(c) confirm that Beijing 2015 was UB's best year, whereupon age started to play a role on UB's performance.

Moreoever, we conclude that his bronze medal at London 2017 was mainly due to the bad combination of his mass increment with respect to Rio 2016, the negative tailwind and his high reaction time. At a first sight, one might think that all runners were subject to the same -0.8 m/s tailwind at London 2017. Nevertheless, hydrodynamic drag is proportional to the cross-section of runners. UB being by far the runner with the largest body frame, his cross-section is larger than those of the other runners, being more affected by the drag terms

[3] Actually, reaction times cannot be calculated under hypothetical conditions, because they are in a great part determined by other aspects than the purely physical ones (Hernández-Gómez *et al* 2017).

Table 5. Hypothetical running times of UB from Beijing 2008 to London 2017 calculated with Bolt's mass at Berlin 2009 ($m^{(S)} = 86$ kg).

Event	Original mass $m^{(O)}$ (kg)	Standardised mass $m^{(S)}$ (kg)	$m^{(S)}/m^{(O)}$ (1)	Original time t_O (s)	Standardised time t_S (s)	t_S/t_O (1)	$t_O - t_S$ (s)
Beijing 2008	86	86	1.000	9.69	9.69	1.000	0.000
Berlin 2009	86	86	1.000	9.58	9.58	1.000	0.000
London 2012	93	86	0.925	9.63	9.53	0.989	0.102
Moscow 2013	93	86	0.925	9.77	9.67	0.990	0.099
Beijing 2015	94	86	0.915	9.79	9.68	0.989	0.112
Rio 2016	94	86	0.915	9.81	9.70	0.988	0.114
London 2017	95	86	0.905	9.95	9.82	0.987	0.125

Table 6. Hypothetical running times of UB from Beijing 2008 to London 2017, with the same tailwind ($v_w^{(S)} = 0$ m/s) and mass ($m^{(S)} = 86$ kg) conditions.

Event	Original mass $m^{(O)}$ (kg)	Original wind speed v_O (m/s)	Original time t_O (s)	Standarised time t_S (s)	$t_O - t_S$ (s)
Beijing 2008	86	0.00	9.69	9.69	0.00
Berlin 2009	86	+0.90	9.58	9.67	−0.09
London 2012	93	+1.50	9.63	9.69	−0.06
Moscow 2013	93	−0.30	9.77	9.64	+0.13
Beijing 2015	94	−0.50	9.79	9.63	+0.16
Rio 2016	94	+0.20	9.81	9.72	−0.09
London 2017	95	−0.80	9.95	9.74	−0.21

of the model than the other sprinters. Considering this hydrodynamic disadvantage, UB probably would have won at London 2017 even with his brand new 95 kg mass, if this race would not have had such a negative tailwind. This fact raises interesting questions for physiologists and trainers: is it possible to train/feed a high-performance sprinter to increase his exerted force while preserving or diminishing his cross-section? Is this possible while he ages?

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References

Eurosport 2018 Usain Bolt—player profilehttp://eurosport.com/athletics/usain-bolt_prs55530/person.shtml
Helene O and Yamashita M 2010 *Am. J. Phys.* **78** 307–9
Hernández-Gómez J J, Gómez R W and Couder-Castañeda C 2017 *Eur. J. Phys.* **38** 054001
Hernández-Gómez J J, Marquina V and Gómez R W 2013 *Eur. J. Phys.* **34** 1227
IAAF 2017 100 metres result—IAAF World Championships London 2017 https://www.iaaf.org/results/iaaf-world-championships-in-athletics/2017/iaaf-world-championships-london-2017-5151/men/100-metres/final/result