Breaking the Cycling Hour Record: Is There Still Room for Altitude?

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Dear Editor-in-Chief,

By impressively modeling nearly five hundred cycling hour record (CHR) attempts, Harnish et al. (1) found only a small effect of altitude, with an improvement of 0.075 km/h at an optimal altitude of 1200 m. Yet, previous physiological models predicted larger improvements at optimal altitudes of 3500 m (2) and 2500 m (3). Thus, is it still worth attempting the CHR at altitude? To answer this question, I updated two physiological models addressing CHR (2, 3). One was developed by di Prampero (2) and focuses solely on aerodynamic resistances. In the other, Bassett et al. (3) quantified both non-aerodynamic and aerodynamic resistances.

The underestimation of the decline in $\dot{V}O_{2max}$ with altitude in endurance athletes has often been cited as an explanation for the difference in model predictions (1–3). However, both di Prampero (2) and Bassett et al. (3) modeled the $\dot{V}O_{2max}$ decline in hypoxia using data from athletes, although from different sources. Thus, the first update is to adopt the state-of-the-art $\dot{V}O_{2max}$ vs. altitude curve from the meta-regression of MacInnis et al. (4), which is steeper the higher the baseline $\dot{V}O_{2max}$, and to select the maximum value of baseline $\dot{V}O_{2max}$ of the data they used to estimate the curve (75 ml/kg/min) (**Table**). This results in possibly the steepest $\dot{V}O_{2max}$ vs. altitude curve in the literature. Although developed for acute hypoxia, it is conservative to assume that it applies to acclimatized athletes in this context. In fact, the maximum 1-h power (MhP) is reasonably more compromised than $\dot{V}O_{2max}$ upon acute altitude exposure (5, 6), making acclimatization necessary to restore MhP to the expected values based on acute $\dot{V}O_{2max}$.

Temperature was assumed constant regardless of altitude, as in di Prampero (2). Bassett et al. (3) originally calculated air density from Standard Atmosphere, which assumes 15 °C at sea level and a drop of 6.5 °C/km (7). Therefore, it was recalculated assuming a warm velodrome temperature (8) at each altitude. The data of the current CHR record holder, Filippo Ganna, were used (**Table**).

The results are shown in the **Figure**, and indicate that:

1. with the most "penalizing" $\dot{V}O_{2max}$ vs. altitude curve ever adopted (4), physiological modeling predicts an optimal altitude of 2100 m and 1400 m for the updated models of di Prampero (2) and Bassett et al. (3), respectively;
2. minimizing *non*-aerodynamic resistances (as in di Prampero's model (2), which represents a theoretical "technological" limit of zero mechanical frictions) can be a very effective strategy to enhance the positive effect of altitude on CHR;
3. the most conservative physiological model (3) still predicts a greater improvement in CHR with altitude compared to historical data modeling (1). It also predicts that at 1400 m altitude, Filippo Ganna could improve his current CHR by 190 m.

In conclusion, the assumption of a greater decline in $\dot{V}O_{2max}$ with altitude is not sufficient to explain the differences between physiological modeling and historical data modeling on CHR. This discrepancy may be attributed to higher non-aerodynamic resistances at altitude (e.g., rough track surface, tight turns) (3) or reduced time-trial performance due to incomplete acclimatization (6). There is still room for altitude to break the hour record.

References

1. Harnish CR, Swinand GP, Fisher AE. Making History in 1 h: How Sex, Aging, Technology, and Elevation Affect the Cycling Hour Record. *Med Sci Sports Exerc*. 2024;56(3):454–63.
2. di Prampero PE. Cycling on Earth, in space, on the Moon. *Eur J Appl Physiol*. 2000;82(5):345–60.
3. Bassett DRJ, Kyle CR, Passfield L, Broker JP, Burke ER. Comparing cycling world hour records, 1967–1996: modeling with empirical data. *Med Sci Sports Exerc*. 1999;31(11):1665–76.
4. MacInnis MJ, Nugent SF, MacLeod KE, Lohse KR. Methods to Estimate $\dot{V}$O2max upon Acute Hypoxia Exposure. *Med Sci Sports Exerc*. 2015;47(9):1869–76.
5. Fulco CS, Rock PB, Cymerman A. Maximal and submaximal exercise performance at altitude. *Aviat Space Environ Med*. 1998;69(8):793—801.
6. Mateo-March M, Muriel X, Valenzuela PL, et al. Altitude and Endurance Performance in Altitude Natives versus Lowlanders: Insights from Professional Cycling. *Med Sci Sports Exerc*. 2022;54(7):1218–24.
7. International Organization for Standardization. Standard Atmosphere. *ISO 2533:1975*. 1975; Available from: https://www.iso.org/standard/7472.html.
8. Kordi M, Bigham D, Tipper J, Ferguson RA, Howatson G, Wale J. Case study of a world hour record simulation in an elite cyclist: Insight into task failure. *Eur J Sport Sci*. 2024;24(12):1779–87.

Table. Input variables of the two models.

Factors used in both models (2, 3)		
Factor	**Value**	**Source**
$\dot{V}O_{2max(h)}/\dot{V}O_{2max(0)}$	$[75 - 5.5913\ (7.7328 - 1.1872\ h - 0.294 \times 75 + 0.0777\ h^2 + 0.0027 \times 75^2 + 0.0283\ h \times 75)]/[75 - 5.5913\ (7.7328 - 0.294 \times 75 + 0.0027\ 75^2)]$ (for a baseline $\dot{V}O_{2max}$ of 75 ml/kg/min)	(4)
$P_{B(h)}/P_{B(0)}$	From the Standard Atmosphere	(7)
$\rho_{(h)}/\rho_{(0)}$	$P_{B(h)}/P_{B(0)}$ (constant temperature at every altitude)	(2)
Filippo Ganna's factors during the 2022 hour record inserted in Bassett et al. model (3)		
Factor	**Value**	**Source**
Rider position (k_{po})	1.0 (standard position with aero bars, elbows in)	(3)
Bicycle (k_b)	0.97*	(3)
Clothing (k_c)	0.98 (optimum weave material)	(3)
Height (l)	193 cm	Internet
Body mass (m)	83 kg	"
Bicycle mass (b)	9 kg	"
Speed	56.792 km/h	"
Altitude	450 m (Grenchen, Switzerland)	"
Temperature	26 °C	"

*arbitrary average between classic track bikes (1.0) and the banned "aero" bike (0.93)

di Prampero's approach (2) calculates the maximum 1-h speed relative to sea level as:

$$v_{(h)}/v_{(0)} = [\dot{V}O_{2max(h)}/\dot{V}O_{2max(0)}/(\ P_{B(h)}/P_{B(0)})]^{1/3}$$

Bassett et al.'s approach (3) calculates the 1-h power of a known cycling hour record attempt as:

$$MhP = 0.00953\ (m+b)\ v + 0.00775\ v^2 + P_{B(h)}/P_{B(0)}\ 288/299\ k_{po}\ k_b\ k_c\ (0.0293\ l^{0.725}\ m^{0.425} + 0.0604)\ 0.007551\ v^3$$

It then calculates v at different altitudes, knowing that both MhP and aerodynamic drag decrease by a factor $\dot{V}O_{2max(h)}/\dot{V}O_{2max(0)}$ and $P_{B(h)}/P_{B(0)}$, respectively. The model originally had sea level density at the Standard Atmosphere's temperature (15 °C 288 K), while it is now assumed 26 °C (299 K), from which the factor 288/299.

h, altitude; 0, sea level; MhP, maximum 1-h power; P_B, barometric pressure; v maximum 1-h speed; ρ, air density; $\dot{V}O_{2max}$, maximum aerobic power.

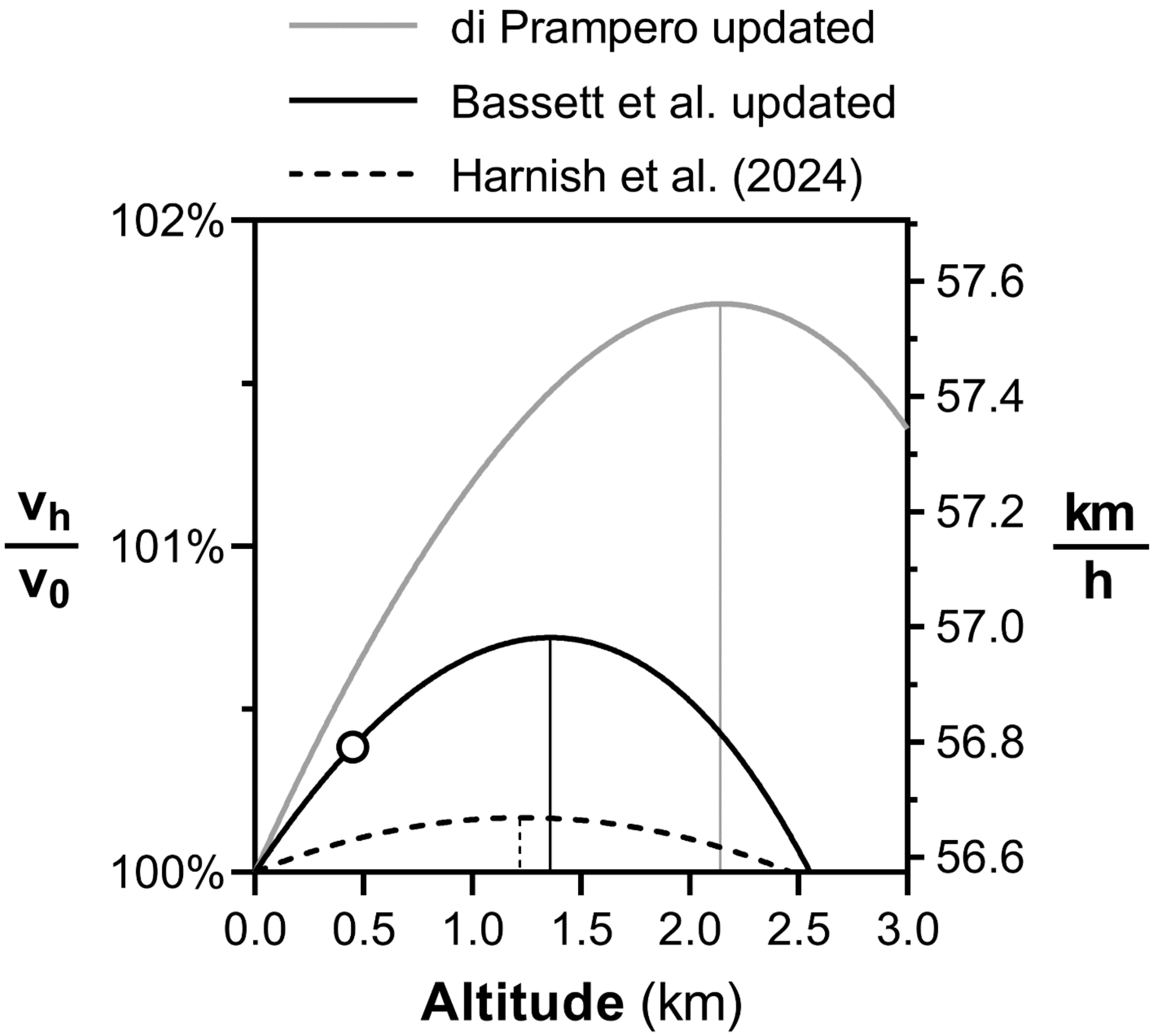

Figure. Maximum hour speed (both relative, $v_{(h)}/v_{(0)}$, and absolute, km/h) as a function of altitude for the three different approaches. The continuous curves are the updated models of di Prampero (2) and Bassett et al. (3). The white dot is the current hour record of Filippo Ganna. The dashed curve was computed from the coefficients provided by Harnish et al. (1) and expressed relative to the rough average distance of all historical male and female data (45 km). Vertical bars indicate optimal altitudes.