

## Conference Abstract

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**Péronnet and Thibault's endurance index predicts maximal aerobic power deterioration over prolonged cycling duration**Jérémy Briand <sup>1,2,\*</sup>, Frédéric Grappe <sup>3,4</sup>, Victor Scholler <sup>3</sup>, Guy Thibault <sup>1</sup> and Jonathan Tremblay <sup>1,2</sup>

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**1 Introduction**

Durability, defined as the ability to resist deterioration in physiological characteristics during prolonged exercise, is increasingly recognized as a key determinant of cycling performance (Maunder et al., 2021). Among the physiological capacities affected by prolonged exercise, the maximal rate of oxygen consumption ( $\text{VO}_{2\text{max}}$ ) and maximal aerobic power (MAP) have been shown to decline substantially, affecting performance in pre-fatigued conditions (Zanini, Folland, & Blagrove, 2025). Péronnet and Thibault (1989) proposed a mathematical model of the power-duration relationship that estimates, from athletes' peak power records (PPR), three physiological parameters: anaerobic capacity,

MAP, and an endurance index (E). E describes the rate of decline in maximal sustainable aerobic power as exercise duration increases beyond the time to reach MAP. We hypothesize that this rate of decline, modeled with E, reflects the deterioration of physiological characteristics such as MAP over prolonged exercise duration, and therefore conceptually overlaps with the durability construct. However, no study has directly examined whether E predicts the magnitude of MAP deterioration during prolonged exercise. The purpose of this study was to investigate the relationship between E and MAP decline across progressive levels of prior work in professional cyclists, while controlling for baseline MAP.



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## 2 Material and Methods

Forty-six professional male cyclists (age:  $23.0 \pm 5.3$  years; body mass:  $67.8 \pm 6.1$  kg;  $\text{VO}_{2\text{max}}$ :  $74.8 \pm 5.8$   $\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ ) participated in this study. Each cyclist completed 10 PPR tests at four levels of prior work (0, 30, 40, and 50  $\text{kJ}\cdot\text{kg}^{-1}$ ). Peak power was recorded with a power meter (Shimano FC-R9200, Japan) over durations ranging from 15 to 3600 s. The Péronnet-Thibault model was fitted to each athlete's mean PPR profile at each prior work level using nonlinear least-squares regression through the Levenberg-Marquardt algorithm. Anaerobic capacity, MAP, and E were identified for each cyclist at each prior work level. The percentage decline in model-estimated MAP was calculated from the rested condition (0  $\text{kJ}\cdot\text{kg}^{-1}$ ) to each fatigued condition (30, 40, and 50  $\text{kJ}\cdot\text{kg}^{-1}$ ). Because baseline MAP and E were expected to be correlated, partial correlations and multiple linear regressions were used to assess the independent association between E and MAP percentage decline, after controlling for baseline MAP.

## 3 Results

The Péronnet and Thibault model accurately fitted PPR across all conditions as shown in Figure 1, with mean absolute percentage errors (MAPE) of  $1.6 \pm 0.6\%$  (0  $\text{kJ}\cdot\text{kg}^{-1}$ ),  $1.6 \pm 0.8\%$  (30  $\text{kJ}\cdot\text{kg}^{-1}$ ),  $1.8 \pm 0.9\%$  (40  $\text{kJ}\cdot\text{kg}^{-1}$ ), and  $2.3 \pm 1.8\%$  (50  $\text{kJ}\cdot\text{kg}^{-1}$ ). Model-estimated MAP (metabolic power) declined progressively from  $26.7 \pm 2.5$   $\text{W}\cdot\text{kg}^{-1}$  at rest to  $25.6 \pm 3.4$   $\text{W}\cdot\text{kg}^{-1}$  ( $-4.40\%$ ) after 30  $\text{kJ}\cdot\text{kg}^{-1}$ ,  $24.8 \pm 4.0$   $\text{W}\cdot\text{kg}^{-1}$  ( $-7.71\%$ ) after 40  $\text{kJ}\cdot\text{kg}^{-1}$ , and  $23.2 \pm 5.0$   $\text{W}\cdot\text{kg}^{-1}$  ( $-14.03\%$ ) after 50  $\text{kJ}\cdot\text{kg}^{-1}$ , all large and statistically significant reductions ( $p < 0.001$ ; Figure 1, inset). Baseline MAP and E were strongly correlated ( $r = -0.73$ ,  $R^2 = 0.54$ ,  $p < 0.001$ ), confirming the need to control for baseline MAP. Raw correlations between E and MAP percentage decline were positive ( $r = 0.34$  to  $0.43$ ,  $p < 0.05$ ), but after adjusting for baseline MAP, the direction reversed as shown in Figure 2: E was negatively associated with MAP decline at 30  $\text{kJ}\cdot\text{kg}^{-1}$  (partial  $r = -0.47$ ,  $p = 0.001$ ), 40  $\text{kJ}\cdot\text{kg}^{-1}$  (partial  $r = -0.43$ ,  $p = 0.003$ ), and 50  $\text{kJ}\cdot\text{kg}^{-1}$  (partial  $r = -0.37$ ,  $p = 0.010$ ). Multiple linear regressions including both E and baseline MAP explained 68% (30  $\text{kJ}\cdot\text{kg}^{-1}$ ), 63% (40  $\text{kJ}\cdot\text{kg}^{-1}$ ), and 69% (50  $\text{kJ}\cdot\text{kg}^{-1}$ ) of the variance in MAP decline.

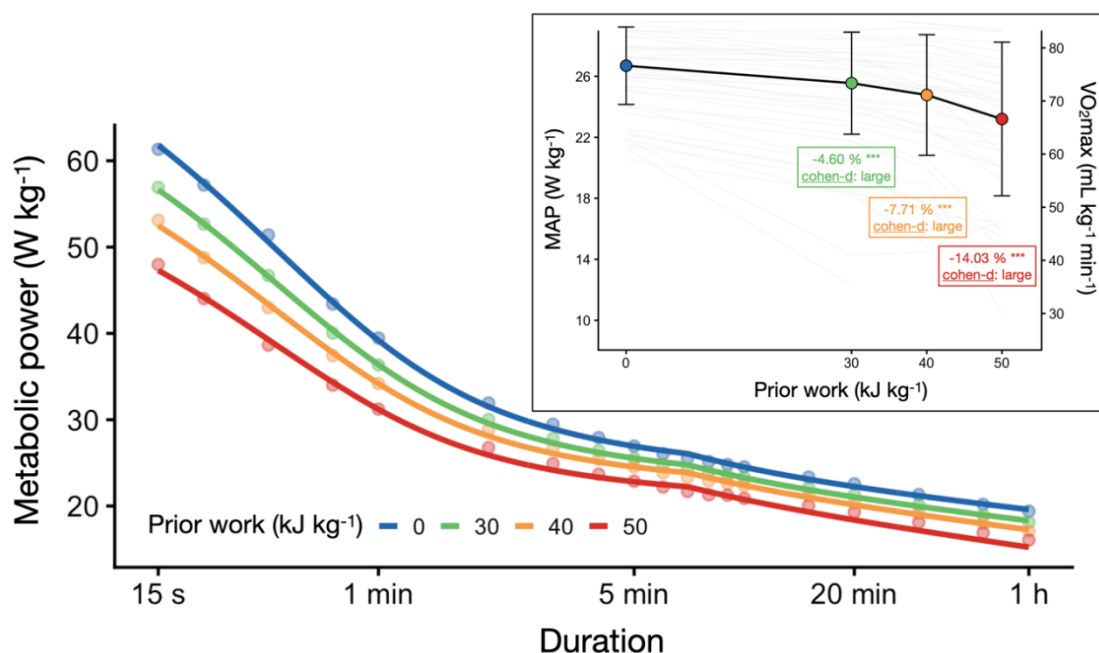


**Figure 1.** Péronnet and Thibault model fits to the group-mean peak-power records at four prior-work levels (0, 30, 40 and 50  $\text{kJ}\cdot\text{kg}^{-1}$ ), expressed as metabolic power. Inset: model-estimated MAP (mean  $\pm$  SD;  $n = 46$ ) across prior-work levels, with the percentage decline from rest (\*\*\*)  $p < 0.001$ ; all cohen-d effect sizes are large).

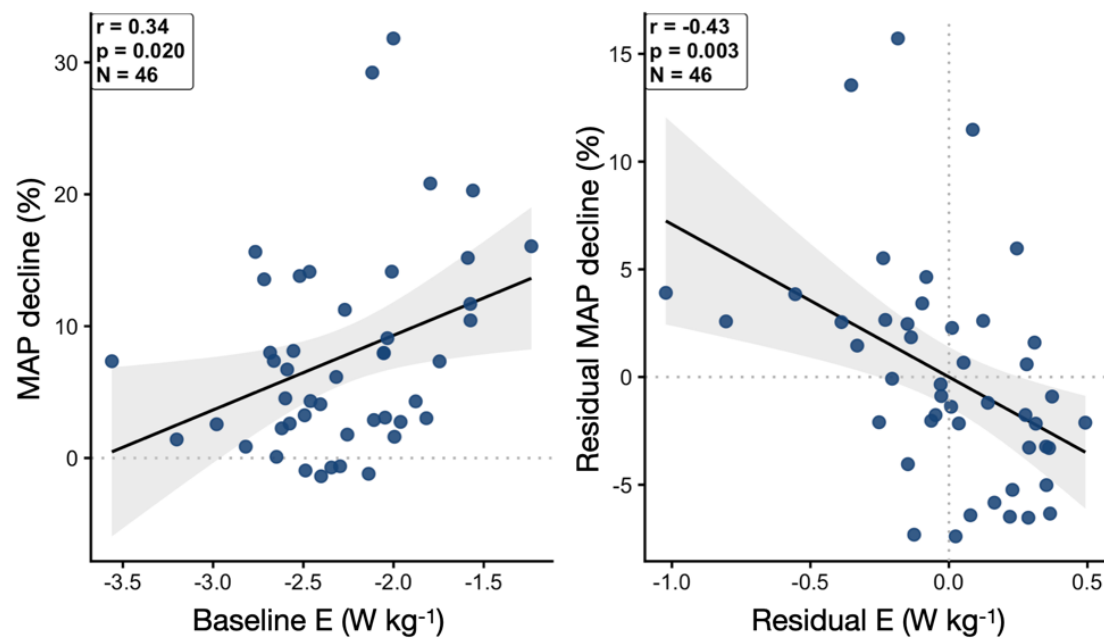


**Figure 2.** Baseline endurance index E (W·kg<sup>-1</sup>) versus MAP percentage decline at 40 kJ·kg<sup>-1</sup>. Left: raw correlation ( $r = 0.34$ ,  $p = 0.020$ ). Right: partial correlation controlling for baseline MAP, shown as residuals ( $r = -0.43$ ,  $p = 0.003$ ). The positive raw association reverses once baseline MAP is held constant ( $n = 46$ ).

## 4 Discussion

These findings confirm the association between E and MAP percentage decline following prior work, after accounting for the confounding effect of baseline MAP. The reversal from positive raw to negative partial correlations underscores the importance of controlling for baseline MAP when interpreting the relationship between E and MAP percentage decline. The strong explained variance (up to 69%) suggests that MAP decline after extended prior work, also referred to as MAP durability (Mauder et al., 2021), is strongly linked to the original endurance index concept proposed by Péronnet and Thibault more than 35 years ago. The current analysis focused solely on MAP decline, but it is reasonable to assume that after prolonged exercise other physiological characteristics, such as gross efficiency and energy substrate utilization, will also change. Including these broader factors could account for the unexplained variance. From a practical standpoint, E offers a simple metric for assessing durability from routinely collected PPR data, without requiring dedicated fatigue protocols.

This index (E) can readily be obtained by fitting the Péronnet and Thibault model to available PPR data. This study is limited by its use of a single professional cycling cohort. Future research should examine whether changes in E over a training season track changes in durability, whether E differs across training levels or competitive categories, and whether these findings extend to female cyclists and other endurance disciplines. Such investigations could inform targeted training interventions aimed at improving this determinant of performance.

## References

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