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Conference Abstract

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Modelling cornering speed in road cycling

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Abstract

Cornering performance is a key factor in downhill road cycling, yet the mechanisms governing speed regulation in turns remain poorly quantified. In this study, three professional cyclists performed repeated descents of a ~3 km road segment, with speed recorded at 10 Hz and turn geometry characterised through curvature. Minimum speeds in turns were found to be consistent across riders and primarily determined by the curvature radius R, with sharper turns leading to lower speeds. This behaviour is well described by a friction-based model $v_{lim} = (\mu^* g^* R)^{1/2}$, which accurately predicts whether braking is required. A dynamical model incorporating this constraint reproduces the measured speed profiles and correctly identifies braking locations. These results demonstrate that a simple friction-based framework captures the main mechanisms governing speed regulation in downhill cycling and can be used to provide pre-race guidance on achievable speeds and appropriate precautions in each turn.

Keywords

road cycling; turns; speed; friction

1 Introduction

Cornering performance is crucial in downhill cycling and time trials, as riders must adjust their speed to road geometry while maintaining control (Zignoli 2020; Zignoli & Biral, 2020). Observations suggest that not all corners constrain speed equally. Lommers (2015) analysed professional cyclists descending a section with eight consecutive turns and found braking in only three, indicating that some corners can be negotiated without slowing. In these three turns, minimum speed was consistent across riders.

Mechanically, the maximum sustainable speed in a turn is limited by tire–road grip and can be expressed as $v_{lim} = (\mu^* g^* R)^{1/2}$, where R is the trajectory radius, g gravitational acceleration,

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and μ the tire–road friction coefficient (Zignoli, 2020). Cornering speed thus depends on both turn geometry and road/tire conditions (Zignoli, 2020; Zignoli & Biral, 2021).

This study aims to determine whether this theoretical speed limit can account for observed speed patterns in professional cyclists descending a road segment.

2 Material and Methods

Three professional male cyclists (mass with equipment 75.4±4.2 kg, age 30±3) performed repeated descents of the same road segment (Figure 1).

Two experimental conditions were tested: in the coasting condition, riders stopped pedalling before turn 1 and remained in freewheel until the end of the descent; in the pedalling condition, they were allowed to pedal throughout. In both cases, riders were instructed to maximise speed while maintaining safe control. After turn 1, the descent contained six turns with maximum curvature above 0.02 m^{-1} (Figure 1), and speed was recorded at 1 Hz using a GPS device.

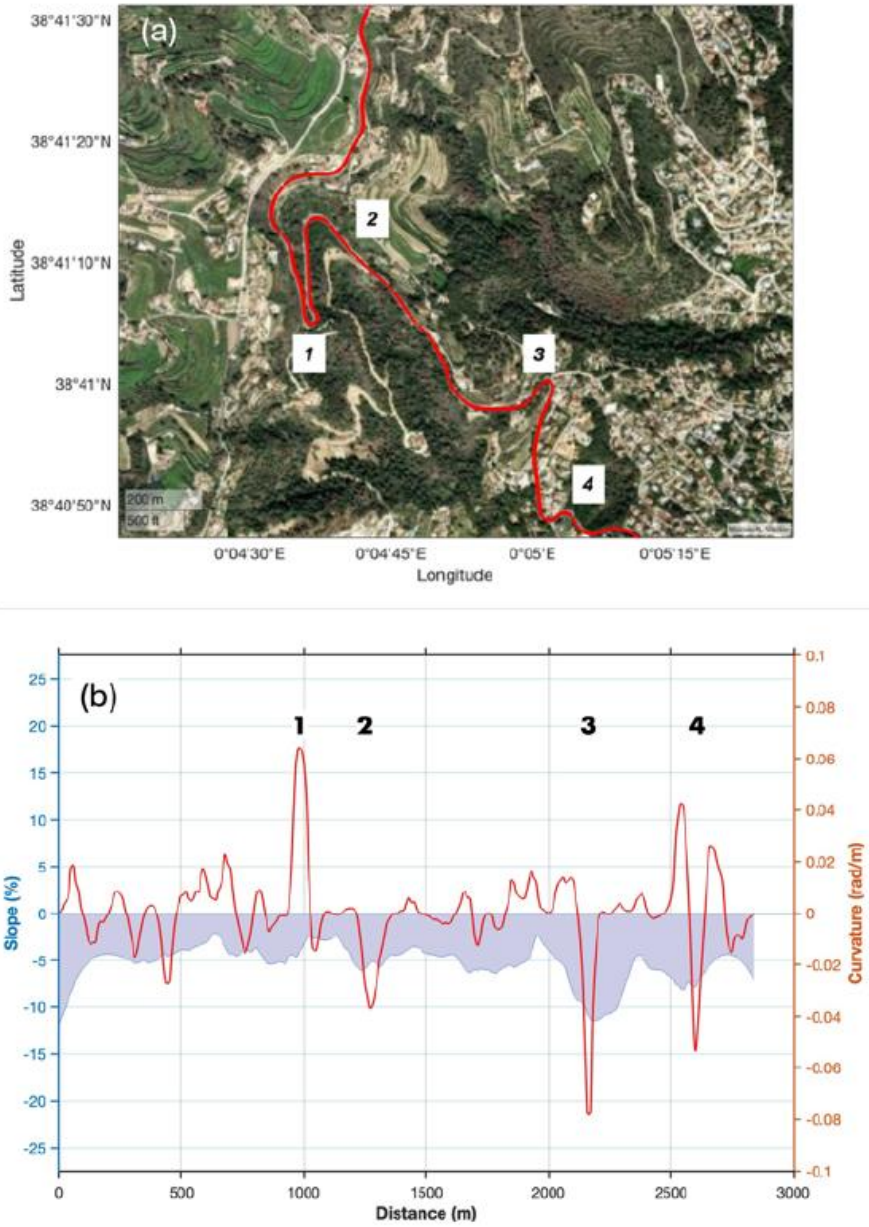


Figure 1. (a) Satellite view of the track. Turn number is indicated next to its location; (b) Curvature and slope as a function of distance.

3 Results

Speed as a function of travelled distance is shown in Figure 2 for all ten trials. Three areas exhibit clear braking events (turns 1, 3 and 4). Turn 2 does not involve braking during the coasting trials, whereas braking is observed during the pedalling trials.

The maximal minimum speed observed in each turn (s1 to s4 for corners n°1 to corner n°4) follows the same order as the maximum absolute value of curvature of the corresponding turn (ie s3 < s1 < s4 < s2). In particular, the lowest speed is observed in turn 3, which corresponds to the highest absolute curvature.

The theoretical speed limit defined by $(\mu^*g^*R)^{1/2}$ was then superimposed on the speed profiles (Figure 3), with $\mu = 0.83$.

The descent dynamics were modelled by integrating the mechanical energy balance:

$$\frac{1}{2}M\frac{dv^2}{dt} = -\frac{1}{2}\rho SC_x v^3 - MgC_{RR}v - Mg\frac{dz}{dt} + P$$

where v is the speed, ρ the air density, SC_x the aerodynamic area, M the total mass, g the gravitational acceleration, C_{RR} the rolling resistance coefficient, and z the altitude (Cohen et al., 2021). The term P denotes the braking power that was set to zero during coasting and defined as $P = -\mu_f Mgv$ during braking, where μ_f is the brake friction coefficient. A backward constraint approach was used to ensure that speed does not exceed the friction-limited threshold $(\mu^*g^*R)^{1/2}$.

The simulated speed profile reproduces the three braking events at the same locations as in the measured data (Figure 4).

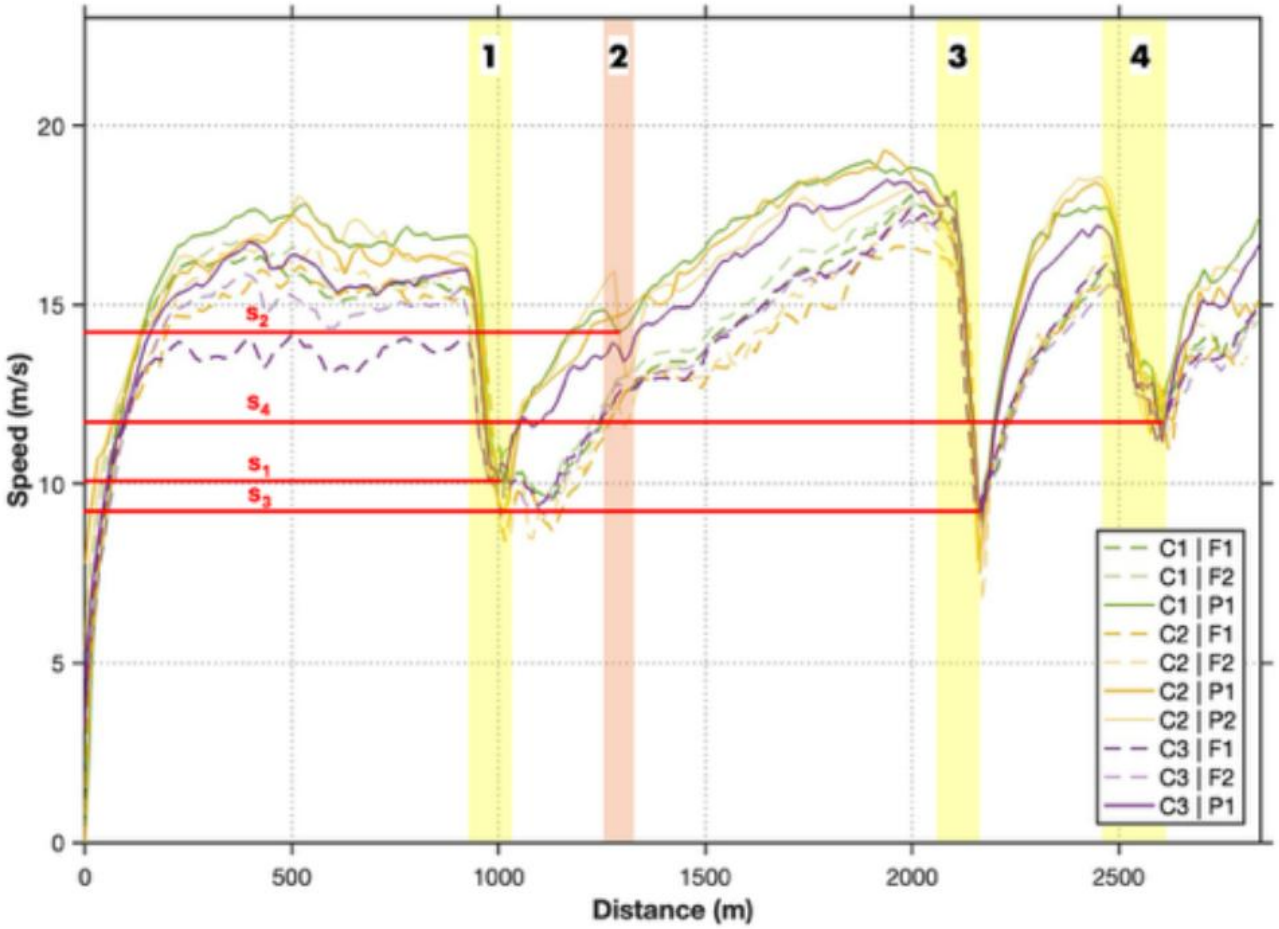


Figure 2. Speed as a function of distance for the three cyclists (C1, C2, C3) on their coasting (F) and pedalling (P) trials. Braking events are highlighted and the corresponding minimal speeds (s1 to s4) indicated in red.

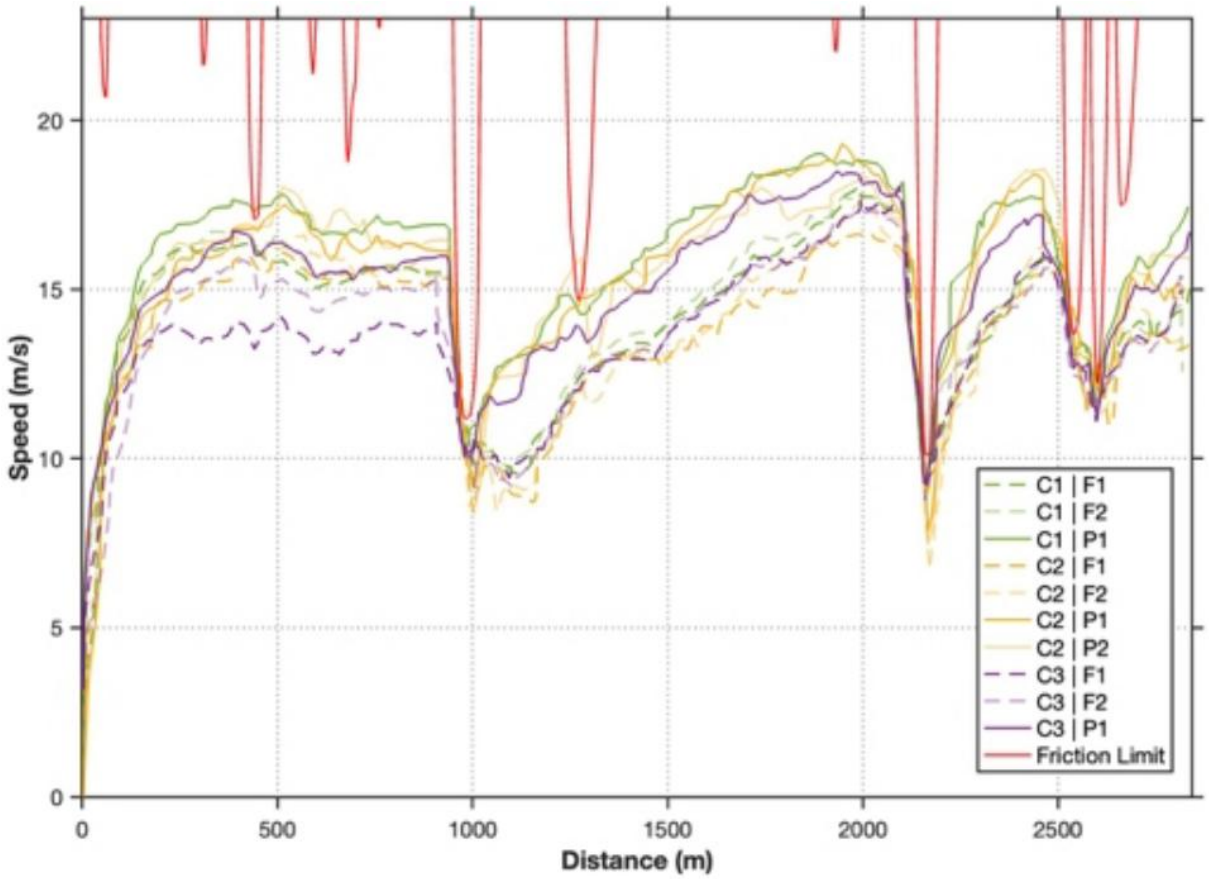


Figure 3. Speed as a function of distance for the three cyclists (C1, C2, C3) on their coasting tests (F) and pedalling ones (P). The speed limit is plotted in black.

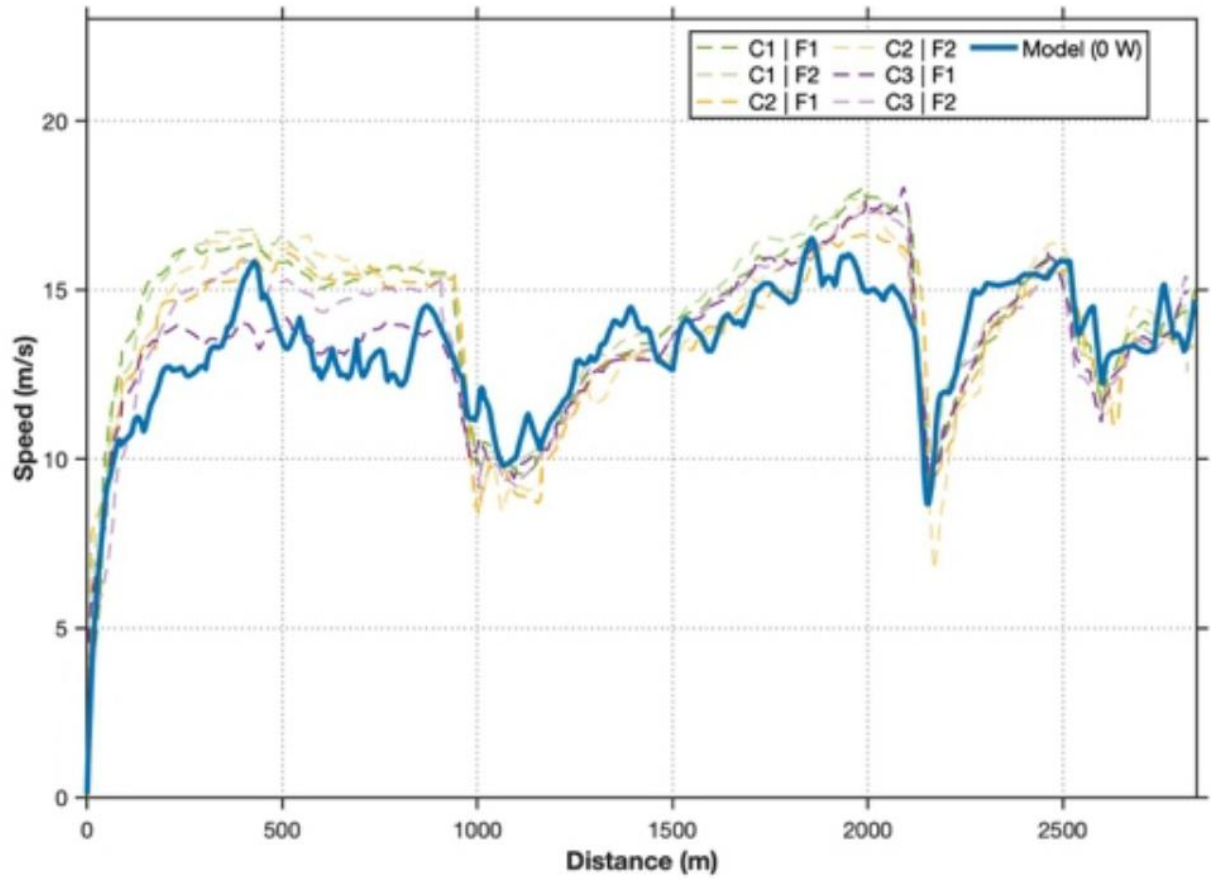


Figure 4. Modelled dynamics for the coasting trials.

4 Discussion

The results demonstrate that a simple friction-based model provides a robust framework to reproduce and interpret observed speed patterns in professional cyclists negotiating curves. The model captures minimum speeds and braking events, showing that speed regulation is governed by the interaction between turn geometry and tire–road grip, with braking occurring where the experimental speed would otherwise exceed the limit.

Braking behaviour is not determined solely by the curvature of a turn but also by approach speed and preceding dynamics, as illustrated by Turn 2. The absence of braking in this turn during the coasting condition can be explained by the lower approach speed, which remains below the speed limit. Whether a cyclist needs to brake in a given turn is influenced by the dynamics leading up to that turn, illustrating the non-local nature of speed regulation in turns.

This also allows to understand how reduced friction, as on wet or degraded surfaces, induces lower speed in turns.

Riding close to the friction-limited speed optimises descent time, however, any misestimation of the speed limit can lead to loss of grip. Moreover, as cyclists often brake before the turn apex, performance depends on rapid assessment of the limit based on incomplete visual information, requiring prediction of turn curvature and road conditions. This framework can provide pre-race guidance on achievable speeds and appropriate precautions in each turn.

5 Conclusions

Minimum speed in turns during professional road cycling is primarily governed by turn geometry and can be accurately described by a simple friction-based model. This study explains both speed regulation and the occurrence of braking, highlighting the dominant role of tire–road grip in downhill performance. Further improvements could account for road width, allowing riders to optimise their trajectory and effectively increase the turning radius, as well as inter-individual differences through rider-specific friction coefficients reflecting technique and risk tolerance. These insights can inform training, strategy, and safety in competitive cycling.

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