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Conference Abstract

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The Impact of Tyre Width, Pressure and Surface Condition on Rolling Resistance and Vibration Transmission of Bicycle Tyres

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Abstract

Rolling resistance and vibration transmission are critical parameters influencing the mechanical efficiency and comfort in competitive cycling. Optimising a tyre setup requires the consideration various metrics such as rider-system mass, tyre width, tyre filling pressure, and surface conditions in parallel. In this study, the combined effects of tyre width and tyre filling pressure on rolling resistance and frame-transmitted vibrations were evaluated under laboratory conditions. Five tyre widths of one tyre model were tested across four rider-system weights, two surface condition (tarmac and cobblestones), and multiple filling pressures. The experiments showed significant non-linear relationships between tyre width, filling pressure, and rolling resistance, with surface conditions contributing a secondary effect. A Vibration analysis revealed that wider tyres substantially reduce surface-induced accelerations, whereas tyre pressure showed a minor but detectable influence. These findings support the development of rider-specific optimisation indices that balance rolling resistance and vibration sensitivity. Further research should integrate physiological responses to vibratory stimuli to refine setup recommendations for individual athletes.

Keywords

rolling resistance; vibration transmission; tyre pressure; tyre width; bicycle dynamics; treadmill testing

1 Introduction

Reducing rolling resistance is a major objective in competitive cycling, as it directly influences mechanical efficiency and the rider's performance. Tyre manufacturers and equipment suppliers typically provide setup guidelines primarily aimed at ensuring safe operation, such as minimum inflation pressures defined by ISO 5775 [1] and ETRTO [2]. However, achieving optimal performance requires a more nuanced setup, considering variables such as rider-system mass, tyre width, inflation pressure, and surface condition [3–6].

Recent research has also emphasised the impact of surface-induced vibration transmission on rider fatigue and metabolic cost [7,8]. Vibrations transmitted through the bicycle frame not only reduce comfort but also elevate neuromuscular strain, particularly during prolonged exposure to rough surfaces such as cobblestones [7-9]. Thus, tyre parameters affect not only rolling efficiency, but also vibratory stress levels imposed on the rider.

Existing manufacturer guidelines and previous studies tend to focus on isolated parameters, often neglecting the complex interactions between rolling resistance and vibration transmission, especially under dynamically changing surface conditions. Furthermore, the rapid evolution of tyre and wheel technologies challenges the maintenance of up-to-date, evidence-based setup recommendations.

This study investigates the combined influence of tyre width, tyre filling pressure, and surface condition on both rolling resistance and vibration transmission. A controlled coast-out test on a dynamic laboratory treadmill (p.a.v.e.) [10] was used to systematically analyse the effects of multiple configurations. The goal is to provide detailed insights into the trade-offs involved and to establish a foundation for individualised set-up strategies that balance mechanical efficiency and vibratory load exposure.

2 Material and Methods

2.1 Experimental Set-Up

Rolling resistance and vibration transmission were measured using a dynamic laboratory treadmill system (p.a.v.e., cf. Fig. 1) previously introduced by the authors [10].

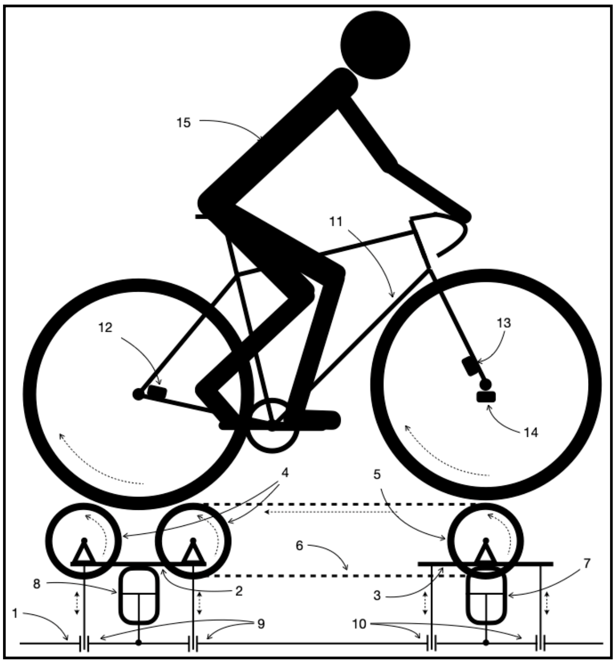

Figure 1. General schematic of p.a.v.e.

The test rig allows coast-out experiments under controlled surface conditions, either smooth tarmac-like (TRMC) or cobblestone-simulated (CBST). Surface irregularities for CBST were simulated by dynamically lifting and dropping the treadmill platforms using pneumatic drives, creating periodic 150 mm long and ~4 mm high surface obstacles synchronised with riding velocity.

2.2 Test Equipment

All tests were conducted using a standardised drop-bar bicycle (V+1, size M, Vielo Sports LTD, Gateshead, United Kingdom), equipped with 700c-23i aluminium rims (G23AR, Token Cycling Products, Taichung, Taiwan) and Continental GrandPrix 5000 tyres (model year 2024, Continental AG, Hanover, Germany). Five tyre widths were evaluated, each mounted with the same TPU tubes (ContiTPU 23/35-622, Continental AG, Hanover, Germany).

2.3 Participants

Four experienced male cyclists (active or formerly active at national level) participated. Subject characteristics were: height 181 ± 2 cm, weight (dressed) 79 ± 3 kg, age 38.5 ± 16.5 years.

Individual rider-bicycle system weights were tightly controlled and maintained constantly across sessions. Weight adjustments were performed using supplemental hydration to achieve ±0.1 kg accuracy.

2.4 Test Protocol

For each combination of tyre width, tyre pressure, and surface condition, five coast-out runs were conducted per rider.

The bicycle was accelerated to an initial speed corresponding to an angular front wheel velocity of >2000°/s (approximately 45 km/h on 32 mm tyres), after which pedalling has been stopped and the system then coasted freely to a complete stop along a straight trajectory.

Tyre pressures were varied across six levels within the manufacturers' recommended ranges (Table 1). For each tyre width, pressures were set in steps of 0.5 bar (±0,02 bar).

Table 1. Tyre ETRTO dimensions, pressure ranges, weights and diameters

ETRTO	pressure range (bar)	actual weight (g)	diameter mounted (mm)
23-622	4.0-8.5	205	676
25-622	4.0-8.5	225	682
28-622	4.0-8.0	245	686
30-622	3.5-7.0	260	688
32-622	3.5-7.0	290	691

2.5 Data Acquisition and Processing

Front wheel angular velocity and triaxial accelerations (x, y, z) were recorded using a synchronised triplet of IMU data loggers (Dialogg, ENVISIBLE GmbH, Chemnitz, Germany) at a sampling rate of 500 Hz, measurement ranges of ±8g and ±2000°/s, at a 16-bit resolution.

The accelerometers were mounted via custom adapters onto the frames flat-mount brake callipers interface on both, front and rear while the third IMU, for measuring angular velocity, was mounted at the front wheels hub.

The coast-out distance (COD) was determined from the front wheel angular velocity measurements and the wheels actual circumference, specifically for the deceleration from 40 km/h down to 10 km/h.

For vibration analysis, the acceleration of the resultant was calculated from the three orthogonal axes. The root mean square (RMS) of this resultant was then computed over the defined speed range (40–10 km/h) for each coast-out run. Signal processing included a 3rd order Butterworth bandpass filter (cutoff frequencies 0.5 and 200 Hz).

Vibrations were analysed individually for front and rear wheel axle. The resulting RMS values were expressed in units of m/s^2. Data preprocessing was performed using DIAdem 2023 software (National Instruments, Austin, USA), and statistical analyses were conducted using MATLAB (R2025a, The MathWorks, Inc., Natick, USA).

Rolling resistance performance was evaluated based on averaged COD across runs. Polynomial regression (third-order) was used to model the relationship between tyre pressure and COD for each configuration. The statistical analysis used a linear mixed-effects model (LME), with rider and test repetition specified as random effects. Fixed effects included tyre width, tyre filling pressure, system weight and surface condition, with interactions and non-linear terms considered, if applicable. The model selection was based on likelihood ratio tests and a stepwise removal of non-significant terms.

3 Results

3.1 Rolling Resistance (Coas-Out Distance)

Coast-out distance (COD) was significantly influenced by tyre width, tyre inflation pressure, and rider-bicycle system weight.

A linear mixed-effects model identified a strong non-linear relationship for tyre width and inflation pressure, with significant quadratic and cubic effects. Wider tyres consistently provided longer CODs across both surface conditions (TRMC and CBST), although the benefit plateaued beyond 30 mm width.

Tyre filling pressure showed a non-linear effect on COD, with an optimal pressure range higher than typically recommended, but still within the manufacturer limits. For each tyre width, a pressure for maximising COD could be determined by third-order polynomial regression (Figure 2).

Rider-system weight correlated negatively with COD, resulting in shorter coast-out distances for heavier systems. However, the interaction between system weight and tyre width partially weakened this effect, as wider tyres appeared less sensitive to weight-induced performance losses.

The surface condition (TRMC vs. CBST) had a statistically significant but rather minor impact on COD (~0.5–1% shorter distances on cobblestones), consistent across all configurations.

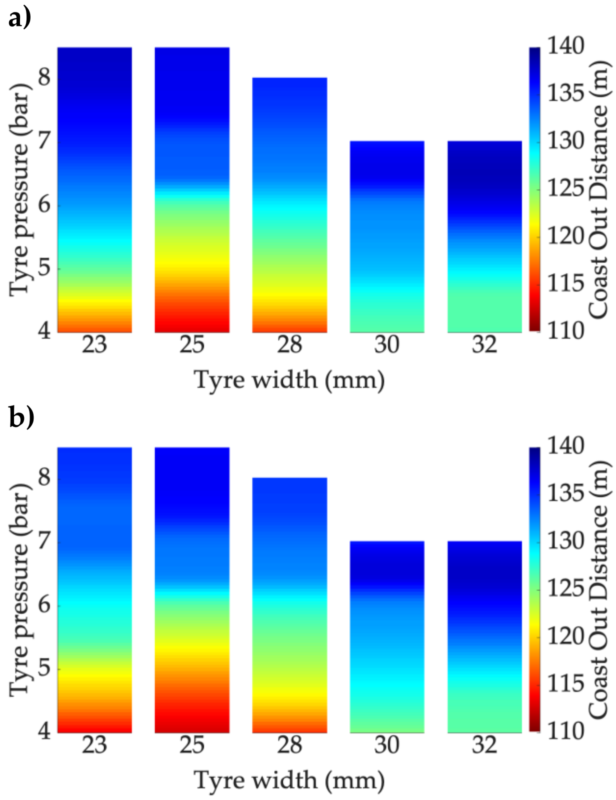

Figure 2. Coast Out Distance (blue being a longer COD vs. red being a shorter COD) over Tyre Width and Tyre Filling Pressure **a)** on Tarmac, **b)** on Cobble Stones.

3.2 Vibration Transmissions (RMS Acceleration)

Resultant RMS accelerations, recorded at the frame, showed a strong dependence on tyre width and surface condition. Wider tyres substantially reduced vibration transmission, particularly under cobblestone conditions (Figure 3).

Tyre filling pressure exerted a secondary influence on vibration behaviour. While higher pressures tended to slightly increase the transmitted vibrations, the tyre width remained the dominant effect.

A distinct difference in measurements could be observed between front and rear wheels. Across all tyre setups and surface conditions the front-mounted accelerometers consistently recorded higher RMS values compared to rear-mounted ones.

Surface conditions strongly affected the absolute vibration levels: RMS values were significantly higher at CBST than on TRMC for all tyre widths and pressures (cf. Fig. 3 & 4)

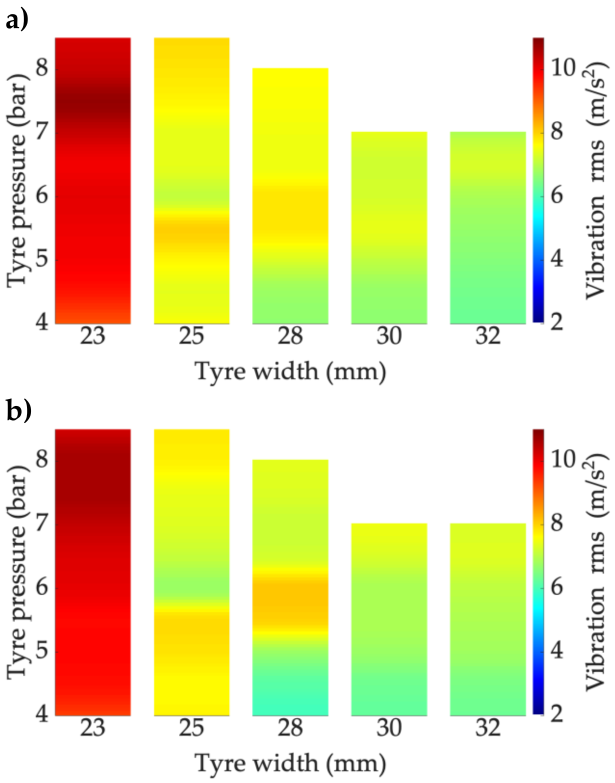

Figure 3. RMS of vibration in m/s² over Cobblestones (red being higher vs. blue being less) over Tyre Width and Tyre Filling Pressure **a)** front, **b)** rear

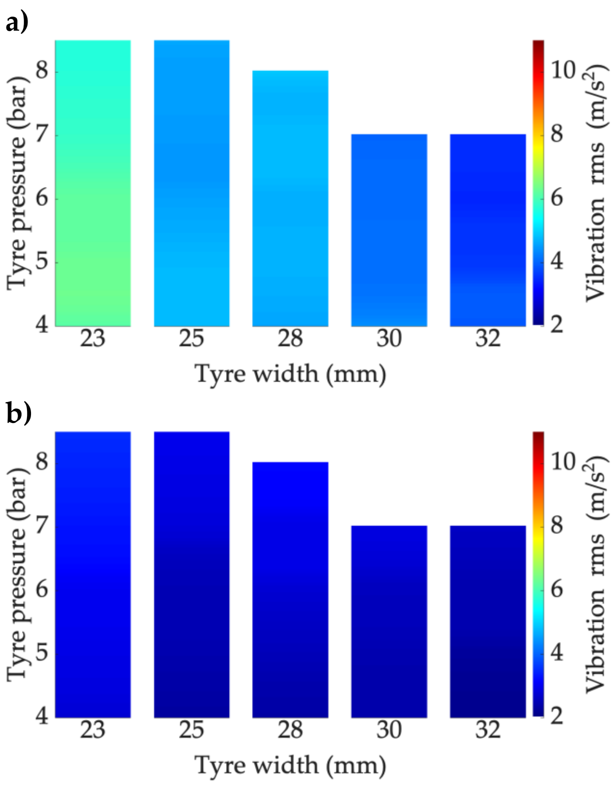

Figure 4. RMS of vibration in m/s² over Tarmac (red being higher vs. blue being less) over Tyre Width and Tyre Filling Pressure **a)** front, **b)** rear

Polynomial regression of vibration RMS against inflation pressure suggested no universal optimum; instead, a trade-off existed between minimising rolling resistance and minimizing vibratory exposure.

3.3 Summary of Key Interactions

- Wider tyres (≥30 mm) achieved the best balance between low rolling resistance and reduced vibration transmission.
- Optimal tyre filling pressures for minimum rolling resistance were higher than common practice, while increasing the vibration transmission moderately only.
- Rider-system weight affected rolling resistance more strongly than vibration transmission within the tested range.
- Surface condition impacted both COD and vibration transmission, but its relative effect was smaller compared to the tyre related parameters.

4 Discussion

4.1 Interpretation of Key Findings

The present study confirmed that tyre width and filling pressure are major determinants of rolling resistance in cycling. Wider tyres consistently demonstrated lower rolling resistance across both tarmac and cobblestone conditions, which is in agreement with previous research [2–5]. However, the benefit of increasing tyre width appeared to plateau beyond 30 mm.

Optimal filling pressures for minimum rolling resistance were higher than typically applied but remained within manufacturer-specified range. These results suggest that current field recommendations may underestimate the performance potential achievable with precise pressure optimisation and settings.

Vibration analysis revealed that wider tyres also substantially reduced transmitted vibratory loads, supporting their dual advantage for both mechanical efficiency and rider comfort. The impact of tyre filling pressure on vibration transmission was secondary but not negligible, particularly on rough surfaces.

4.2 Trade-Offs Between Rolling Resistance and Vibration Exposure

Although higher tyre filling pressures improved coast-out distance, they tended to slightly increase vibration transmission. Therefore, an optimisation purely targeting rolling resistance might come at the cost of increased vibratory exposure to the rider.

The observed asymmetry in vibration transmission in front and rear further highlights the need for differentiated setup strategies for front and rear wheels, particularly for cobblestone racing scenarios.

These findings advocate for the development of rider-specific optimisation strategies that integrate both mechanical and biomechanical performance parameters, rather than focusing solely on rolling resistance.

4.3 Implications for Bicycle Setup Strategies

The results suggest that wider tyres (≥30 mm) and individually optimised inflation pressures can provide tangible performance advantages without compromising rider comfort.

The ability to fine-tune tyre setups based on measurable vibration exposure offers a promising road map for individualised equipment strategies, particularly in races involving varying and rough surface conditions (e.g., Paris-Roubaix, Strade Bianche).

4.4 Limitations

The treadmill-based coast-out methodology used in this study introduces minor systematic differences compared to field conditions. Specifically, the drum diameter (200 mm) may induce slightly higher tyre deformations compared to planar surfaces, necessitating caution when directly transferring absolute tyre filling pressure values to field application.

Furthermore, coast-out tests inherently isolate rolling resistance from propulsion-related energy losses (e.g., stick-slip phenomena on wet cobblestones). As such, real-world influences like traction loss under dynamic pedalling loads were not captured.

The vibration analysis, while comprehensive, focused on resultant RMS accelerations and did not include detailed frequency domain decomposition. Future studies should incorporate spectral analysis to better understand specific vibration modes relevant to rider biomechanics.

4.5 Future Research Directions

Future investigations should extend the range of rider-system masses to explore scaling effects more comprehensively.

The integration of physiological measurements, such as metabolic cost and neuromuscular fatigue markers, will be essential to quantify the real-world impact of vibratory exposure and to derive rider-specific sensitivity profiles.

Additionally, aerodynamic trade-offs associated with wider tyre setups should be systematically incorporated into optimisation frameworks to provide a truly holistic bicycle setup recommendation.

5 Practical Applications

The findings of this study provide a framework for practical optimisation of bicycle tyre setups for competitive use:

- Tyre Width Selection: Riders targeting maximum mechanical efficiency and reduced vibration exposure should prefer tyres with a width of at least 30 mm. Wider tyres (up to 32 mm) showed no significant further reduction in rolling resistance but enhanced vibration damping.
- Tyre Filling Pressure Optimisation: Pressures should be individually optimised using coast-out testing methods. Optimal pressures for minimum rolling resistance were higher than typical field settings but remained within safe limits specified by tyre and rim manufacturers.
- Surface-Specific Setup: For mixed or rough surface conditions (e.g., cobblestones), a slight reduction in inflation pressure compared to the tarmac-optimal setting can be considered to further reduce vibratory loads without substantially increasing rolling resistance.
- Front vs. Rear Differentiation: Given the observed asymmetry in vibration transmission, front wheel setups should prioritise enhanced vibration damping more strongly than rear wheels, particularly for cobblestone races.
- Integration into Rider-Specific Strategies: Future bike setting protocols should integrate mechanical coast-out testing and vibration measurements to develop rider-specific setup recommendations balancing efficiency, comfort, and fatigue management.

The presented treadmill-based coast-out methodology (p.a.v.e.) offers a practical and reproducible approach to derive such individualised optimisations.

6 Conclusions

This study systematically evaluated the combined effects of tyre width, filling pressure, and surface condition on rolling resistance and vibration transmission under controlled laboratory conditions.

The findings confirmed that wider tyres (≥30 mm) and individually optimised filling pressures can significantly reduce rolling resistance while lowering vibratory loads transmitted to the rider at the same time. These effects were consistent across both smooth and cobbled surfaces, with only minor surface-specific adaptations required.

A particular strength of the study lies in the integration of mechanical performance (coast-out distance) and vibratory exposure (RMS acceleration) metrics within a unified experimental framework, enabling a more holistic approach to bicycle setup optimisation.

Future work should extend this methodology by incorporating physiological responses to vibratory stimuli and aerodynamic considerations, thereby facilitating fully individualised, multi-parameter optimisation strategies for competitive cyclists.

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Conflicts of Interest: The authors declare no conflict of interest.

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