AE211 (2024-25-I): Term Project Presentation

AERODYNAMICS OF CYCLIST POSITIONING IN COMPETITIONS

Project No. P-12

INTRODUCTION

In competitive cycling, especially in high-speed track events, aerodynamic drag is the major factor resisting a rider’s motion. Overcoming this drag efficiently becomes crucial, and that's where cyclist positioning plays a key role. By adjusting the relative positions of cyclists especially in formations like pacelines or pelotons riders can take advantage of drafting, where the lead cyclist breaks the airflow, reducing resistance for those behind. This project focuses on understanding how different positioning strategies affect aerodynamic performance, aiming to identify which configurations offer optimal drag reduction.

OBJECTIVES

- **Examine the principles of cycling aerodynamics:**

  A cyclist experiences aerodynamic forces such as drag, lift, and rolling resistance, with drag being the most significant at higher speeds. Reducing drag through streamlined positioning and equipment greatly enhances speed and power efficiency.

- **Analyze different cycling positions for aerodynamic efficiency:**

  Different cycling positions like time trial, hoods, and sprint affect aerodynamic drag and energy use. Research shows that lower torso angles and streamlined postures reduce airflow resistance, improving efficiency and speed.

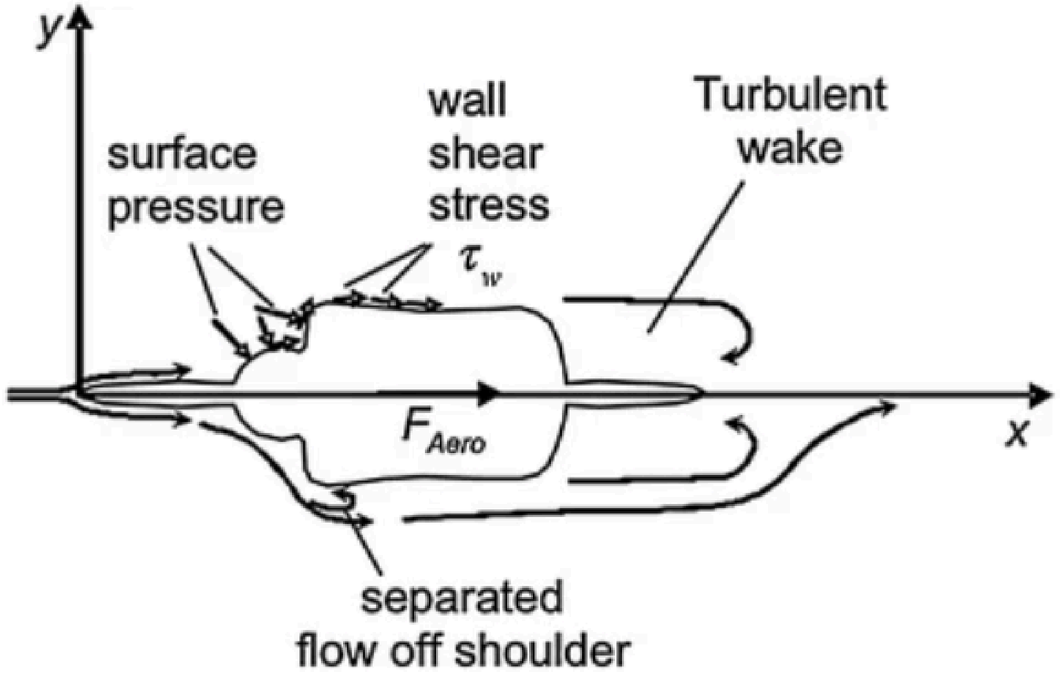
- **Compare CFD simulation data and wind tunnel tests:**

  CFD simulations and wind tunnel tests are used to evaluate aerodynamic performance by analyzing drag, pressure distribution, and airflow. Comparing both methods helps validate accuracy and optimize cyclist positioning for better performance.

PRINCIPLES OF CYCLING AERODYNAMICS

Aerodynamics plays a crucial role in cycling performance, as it directly impacts the rider's speed, efficiency, and overall energy expenditure. Here, we'll explore the fundamental principles of aerodynamics, how body shape and position affect drag, the role of clothing in reducing aerodynamic drag, and practical tips to help cyclists optimise their performance.

Pressure Drag and **Skin Friction** Drag are the main types of aerodynamic drag in cycling.



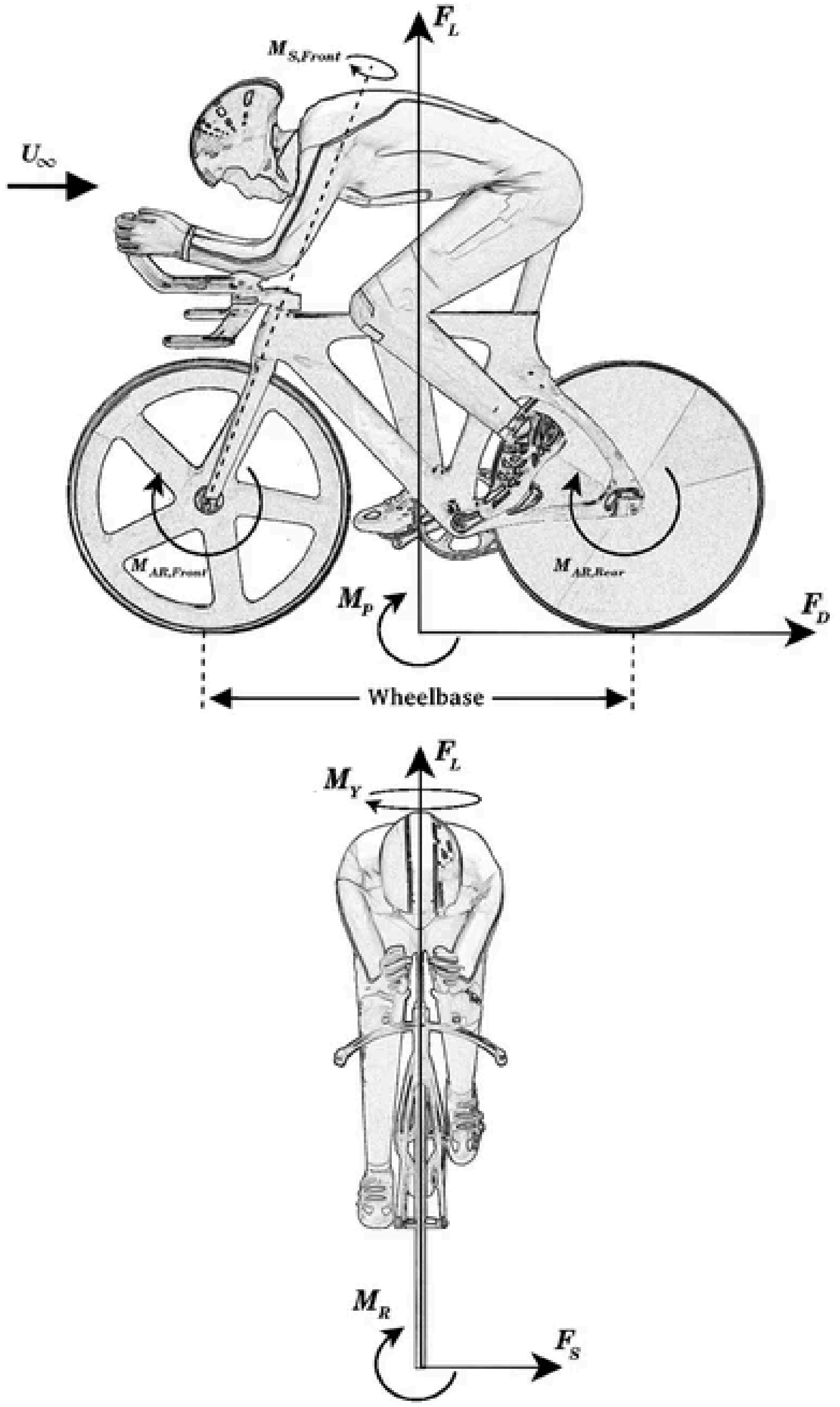
Shape and **Position** of a rider can have a major effect on the drag experienced.

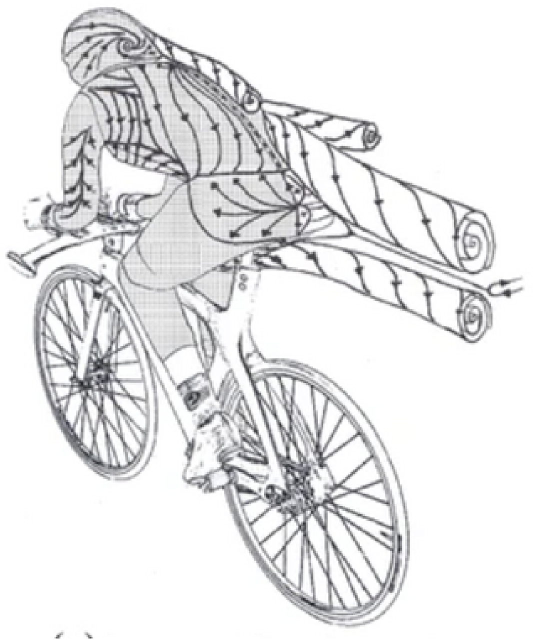
Aerodynamic Forces and Moments:

A cyclist experiences six aerodynamic actions — three forces and three moments:

Forces:

- **Drag** (F_D): Opposes forward motion
- **Side Force** (F_S): Acts sideways due to crosswinds
- **Lift** (F_L): Acts vertically

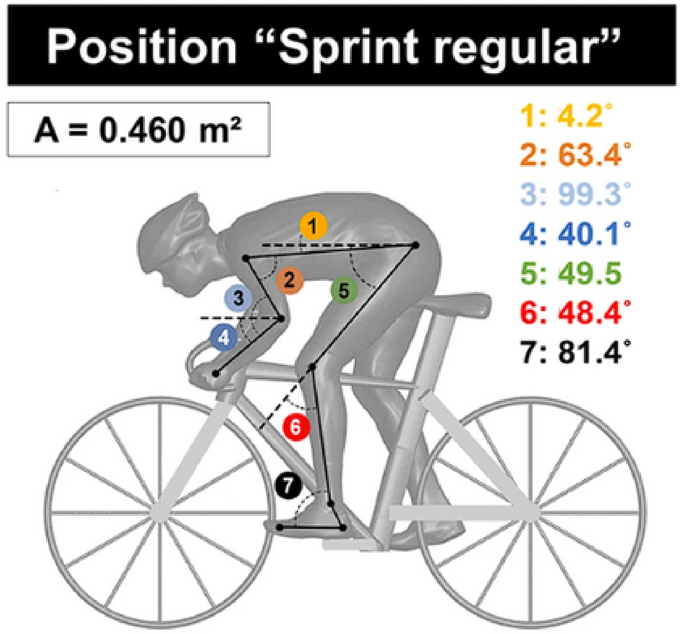




Moments (Torques):

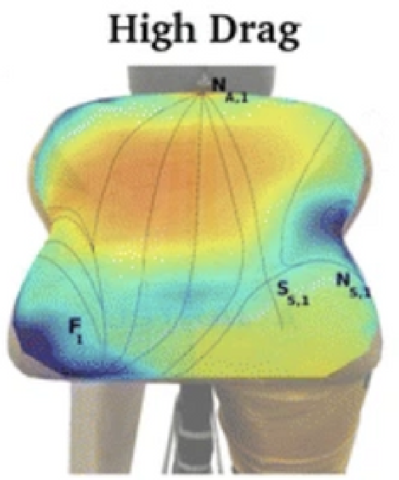
- **Pitching** (M_P): Lifts or lowers the front wheel
- **Rolling** (M_R): Tilts the cyclist side to side
- **Yawing** (M_Y): Turns the front of the bike left or right

ANALYSING CYCLING POSITIONS



Sprint Regular

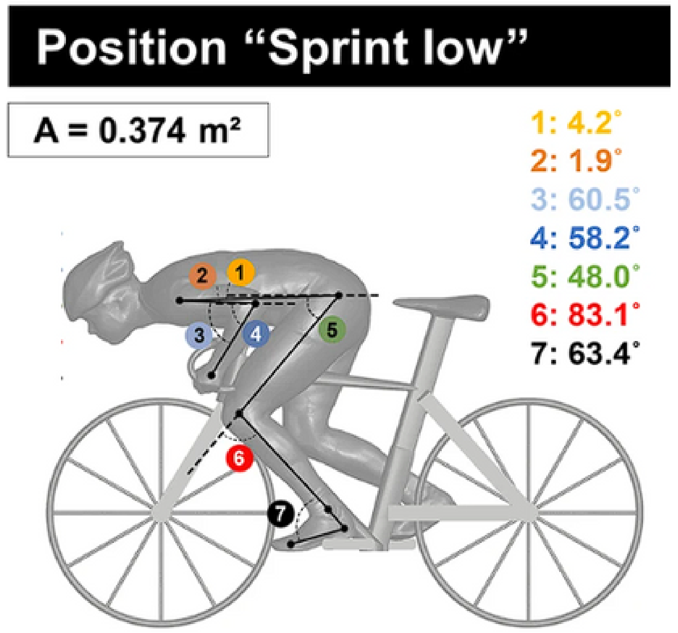
- The rider lowers the torso and tucks in the arms/head to cut drag.
- It is ideal for short sprints where reduced air resistance boosts performance.

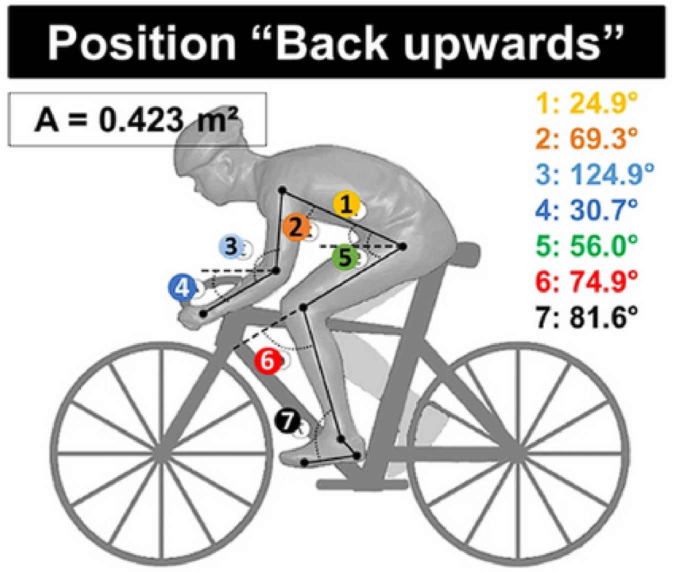


A: frontal area
1: sagittal torso angle
2: shoulder angle
3: elbow angle
4: forearm angle
5: hip angle
6: knee angle
7: ankle angle

Sprint Low

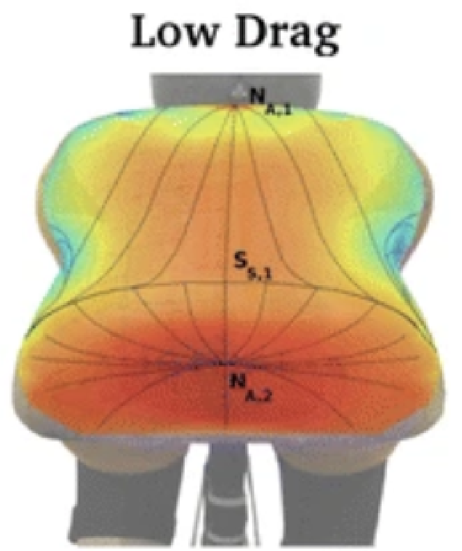
- Torso and arms are even lower and tighter.
- Further reduces drag and turbulence.
- Best for high-speed efforts needing max aerodynamic efficiency.





Back Upwards

- Upright torso increases drag but boosts comfort & visibility.
- It is good for endurance, where control matters more than speed.

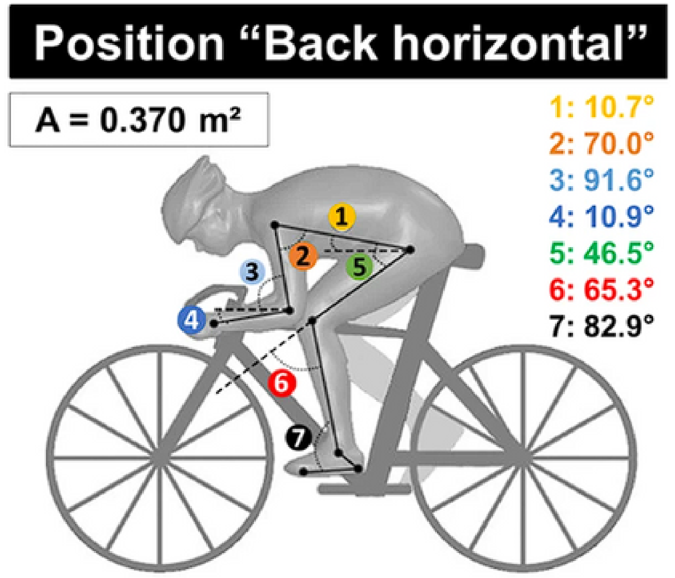


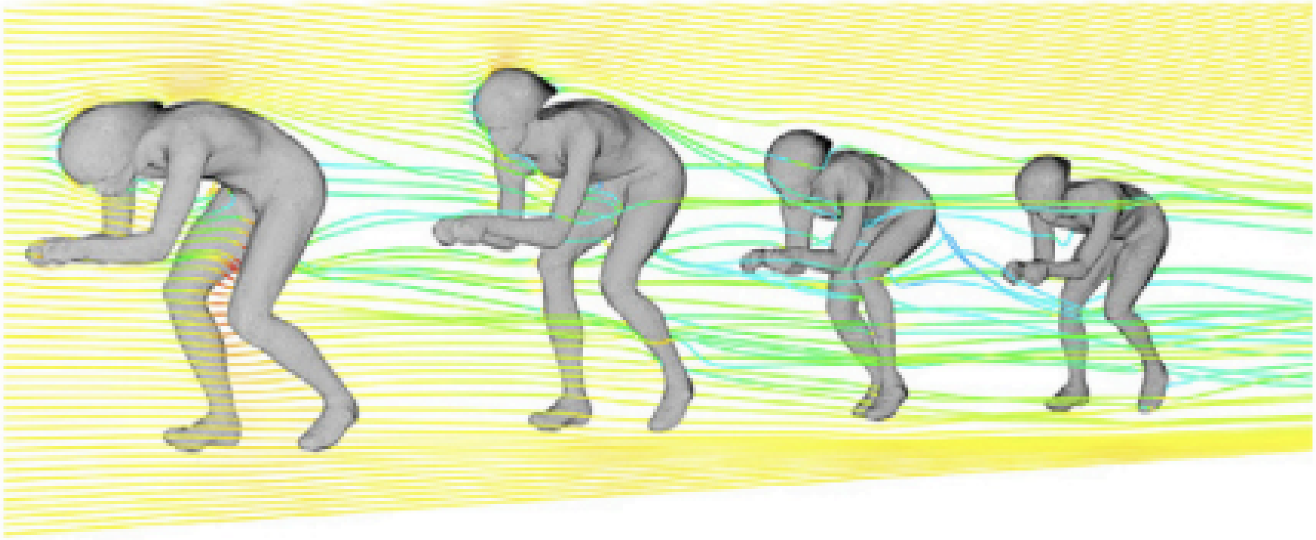
Back Down

- Lowest drag with dropped torso and tight posture.
- Best for max-effort sprints, but less comfortable.

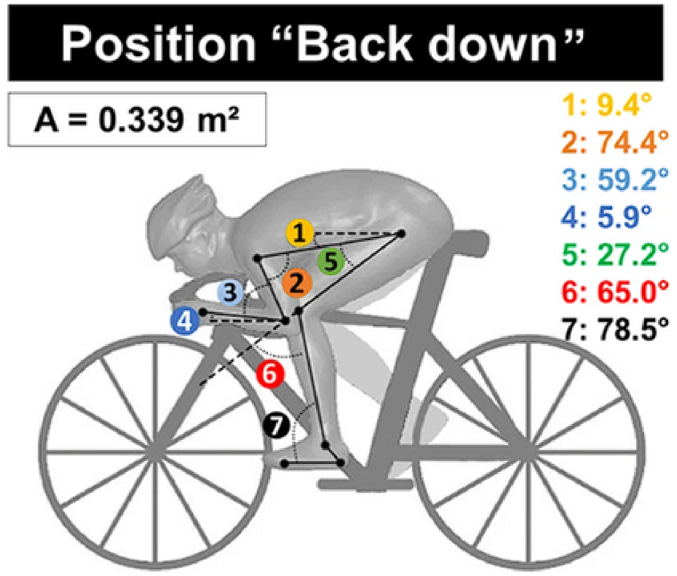
Back Horizontal

- Flat back and tucked arms reduce drag.
- Balances speed and comfort — ideal for time trials.





Velocity-coloured mean streamlines



CFD SIMULATIONS

Purpose of CFD

- To analyze airflow patterns around the cyclist and bicycle setup.
- Quantify aerodynamic drag and visualize pressure/velocity distribution.

Boundary Conditions

- Inlet velocity profile based on competition speeds (e.g., 55+ km/h in time trials).
- Zero-pressure outlet, symmetry planes for lateral sides, and wall for ground.

Key Outputs

- Drag coefficient (C_D) and total aerodynamic drag force (F_D).
- Pressure and velocity contours to identify flow separation and wake zones.

Trends Identified

- Time trial position shows up to 45% drag reduction vs recreational.
- Road racing position achieves ~30% reduction.
- Streamlined gear and posture significantly reduce Cd, supported by frontal area changes.

WIND TUNNEL TESTING

Frontal Area

- Recreational: 0.54 m^2
- Road racing: 0.41 m^2
- Time trial: 0.38 m^2

Accuracy and Repeatability

- Force measurements taken for 30 seconds at 20 Hz.
- Multiple readings per configuration to ensure consistency.
- Minimal standard deviation in Cd.

Drag Variation by Bicycle Type

- Time trial bike: ~36% less drag than mountain bike.
- Road racing bike: ~21% less drag than mountain bike.

Drag Coefficient (C_D) Trends

- ~30% reduction in road racing position.
- ~45% reduction in time trial position compared to recreational posture.

COMPARISON

Advantages of Wind Tunnel Testing

- **High Experimental Accuracy**: Provides direct, validated measurements of drag forces under controlled conditions.
- **Real-World Rider Feedback**: Allows cyclists to test positions and equipment physically, giving immediate biomechanical and comfort insights.
- **Validation Tool**: The gold standard for validating CFD models and ensuring simulation accuracy.
- **Immediate Observation**: Enables visual flow studies (e.g. with smoke or tufts) and quick iteration with physical prototypes.

Advantages of CFD

- **Comprehensive Flow Analysis**: Visualizes airflow, drag sources, and wake effects in great detail beyond what wind tunnels reveal.
- **Cost & Time Efficiency**: Enables rapid testing of multiple designs or rider positions without physical prototypes.
- **Realistic & Custom Scenarios**: Simulates complex conditions like crosswinds, inclines, and dynamic postures not easily recreated in labs.
- **Integrated Optimization**: Supports posture, equipment, and full-system aerodynamic optimization through automated simulations.

CONCLUSION

This project highlights how optimized cyclist positioning significantly reduces aerodynamic drag, enhancing performance in competitive setting. By combining CFD and wind tunnel analysis, we analyse postures to best balance speed and stability.

RESOURCES

1. An Introduction to Cycling Aerodynamics. https://www.rule28.com/blogs/thoughts/an-introduction-to-cycling-aerodynamics

2. CFD Analysis of an Exceptional Cyclist Sprint Position. https://link.springer.com/article/10.1007/s12283-019-0304-7

3. Riding Against the Wind: A Review of Competition Cycling Aerodynamics. https://link.springer.com/article/10.1007/s12283-017-0234-1

4. Increasing road cycling velocity by adopting an aerodynamically improved sprint position. https://journals.sagepub.com/doi/pdf/10.1177/1754337119866962

5. Bicycle aerodynamics. https://www.sciencedirect.com/science/article/pii/S016761052030044

THANK YOU!

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