Full body IMU-Based Analysis of MTB Gravity Sports Biomechanics

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FAST VS SLOW RIDERS: KEY DIFFERENCES

In gravity MTB, small changes in body posture and joint coordination can affect performance [1,2]. This study explored the biomechanical differences between fast and slow riders during six technical turns of a downhill track. Ten experienced riders of varying level wore 15 wireless IMUs (Figure 1) and performed multiple runs. The collected data were analyzed using Principal Component Analysis (PCA) to identify key movement patterns associated with performance.

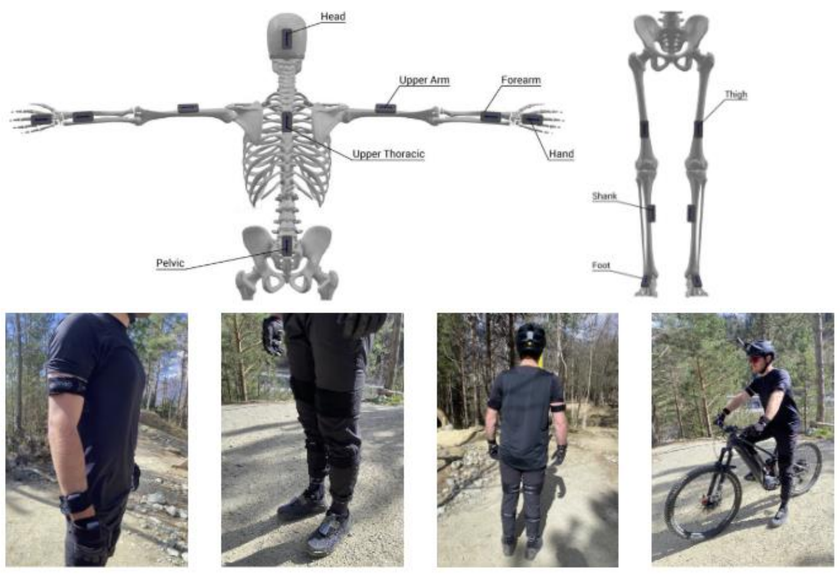

Fig. 1: IMU sensor placement for full-body joint angle tracking.

HOW THE DATA WAS ANALYZED

All joint angle signals were segmented, unwrapped, resampled, and time normalized. PCA was then applied to to each run to reduce dimensionality and identify dominant patterns in rider movements. Each principal component (PC) captured a specific pattern of joint coordination that explained variance across riders. By examining the PC loading, it was possible to determine which joint angle signals contributed most to that pattern. Figure 2 shows the variance explained by each PC for fast and slow groups in one turn, while Figure 3 illustrates key joint angle signals contributing to those PCs, plotted over time.

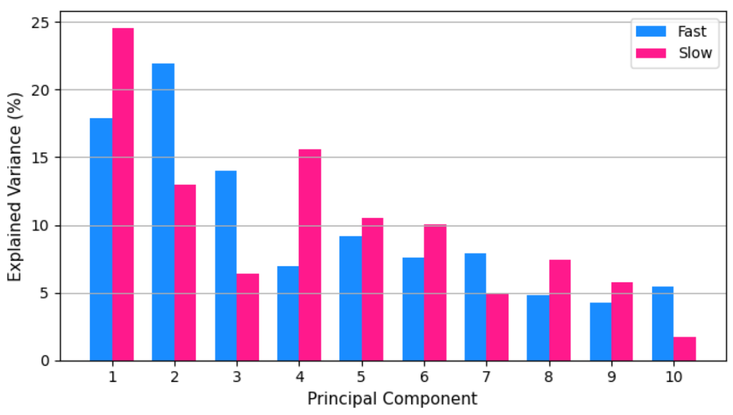

Fig. 2: Explained variance of PCs for fast (blue) and slow (pink) riders.

MOVEMENT STRATEGY OF FAST RIDERS

Fast riders, compared to slow riders, exhibited anticipatory and asymmetrical strategies:

- Greater torso and head lean toward the inside of the curve
- Dynamic flexion-extension patterns in the hips and knees
- Compact postures with low center of mass
- Greater ankle dorsiflexion for improved balance

These strategies are illustrated in Figure 4, showing posture differences during cornering.

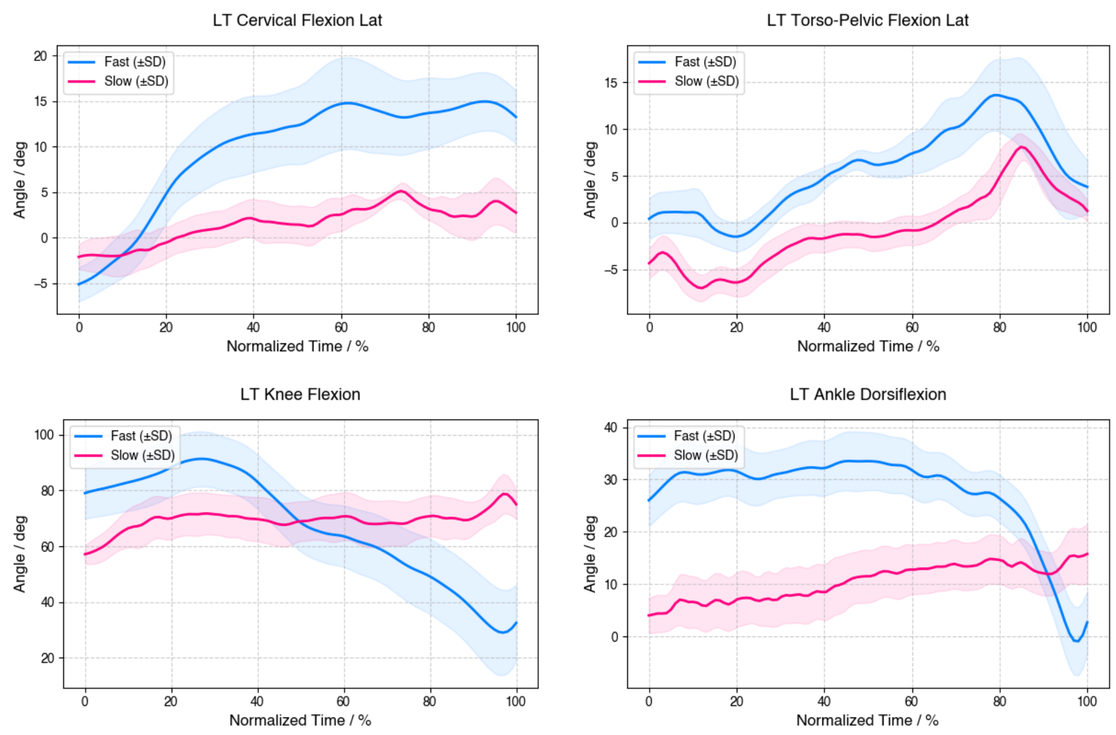

Fig. 3: Example joint angles comparison between fast (blue) and slow (pink) riders.

KEY TAKEAWAYS

Fast riders adopted more proactive and asymmetrical movement strategies, indicating refined motor control and better turn anticipation. These findings highlight the role of temporal coordination, joint-specific asymmetries and adaptive postural adjustments.

This IMU-based approach offers valuable insight for coaches and performance analysis and can support training design, injury prevention, and rider feedback in MTB gravity sports.

Fig. 4: Biomechanical adaptation during cornering of fast (left) and slow (right) rider.

References:
[1] J. B. Chidley, A. L. MacGregor, C. Martin, C. A. Arthur, and J. H. Macdonald, "Characteristics explaining performance in downhill mountain biking," International Journal of Sports Physiology and Performance, vol. 10, no. 2, pp. 183–190, 2015, https://doi.org/10.1123/ijspp.2014-0135.
[2] J. A. H. Virviescas, C. C. de La Portilla, and R. E. A. Bucheli, "Biomechanical comparison between indoor and outdoor cycling focused on studies in real world scenarios," Universidad de los Andes, 2023. [Online]. Available: https://hdl.handle.net/1992/73254
[3] O. Ronzon, Exploring Optimal Body Positioning in MTB Gravity Sports Using IMU Data, Master's thesis, MCI | The Entrepreneurial School, Innsbruck, Austria, 2025.