Automated Biomechanical Analysis of Tennis Serves Using Internet Videos

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Summary

This study proposes an automated framework that can analyze the biomechanics of professional tennis players from internet videos. We employ monocular computer vision (CV)-based pose estimation to investigate biomechanical differences in the tennis serves of a higher-performance player (Player A: 78% first-serve points won) and a lower-performance player (Player B: 56% first-serve points won). Using broadcast footage, 123 serve sequences were extracted and enriched with outcome metadata [2]. Joint angles were calculated through pose estimation, revealing that Player A's serves demonstrated lower joint angle variability and greater consistency in timing. These findings underscore the potential of monocular CV-based pose estimation for conducting detailed biomechanical analyses, enabling broader applications in sports performance research and optimization.

Introduction

Understanding the biomechanical differences between high- and lower-ranked tennis servers can provide valuable insights into performance optimization. Traditional motion capture systems are often impractical for large-scale analysis, necessitating markerless approaches. This study leverages broadcast video and pose estimation to analyze tennis serves.

Methods

Broadcast footage from a grand slam match was analyzed, focusing on players' serves. Pose estimation was conducted using MMpose and MotionBERT [1], resulting in 123 serves tracked (Player A: 69 serves). Metadata, including serve speed and placement, was integrated from publicly available databases [2]. Joint angles were derived from 3D pose data to provide biomechanical context. To standardize serve sequence comparisons, dynamic time warping (DTW) [3] was used to align temporal variations in the serve motion.

Results and Discussion

Player A exhibited significantly lower variability in joint angles compared to Player B, particularly in the shoulder (Figure 1). The consistent timing observed in Player A's shoulder movement throughout the serve sequence contributed to a more repeatable motion pattern, which was also evident across other joints. In contrast, Player B demonstrated irregular movement patterns, with substantial variability occurring predominantly during the mid-serve phase. This variability was associated with improper timing of the swing motion, where some sequences exhibited an early swing onset, while others displayed a delayed swing.

A preliminary analysis found a moderate correlation between elbow joint velocity and serve speed. On second serves, Player A and Player B showed negative correlations of -0.50 and -0.41, respectively. For first serves, the correlations were weaker at 0.25 and 0.18. The negative correlations on second serves suggest that reduced elbow angular velocity aids spin generation, prioritizing precision and consistency over speed.

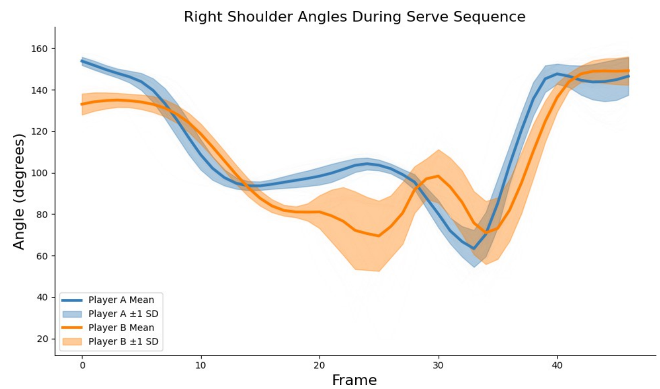

Figure 1: Player A shows a more consistent right shoulder angle throughout the serve sequence compared to Player B

Conclusions

This study demonstrates the feasibility of monocular computer vision for biomechanical analysis in tennis. Key differences in serve mechanics emerged between higher- and lower-performance players, with Player A showing greater consistency in joint angles and timing during critical phases. These findings highlight monocular pose estimation as a scalable, accessible tool for sports biomechanics. Future work will expand the sample size, analyze the kinetic chain, and validate results with ground truth data.

References

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