Vision-Based Neural Network Algorithm for Accessible 8-Stage Biomechanical Tennis Serve Evaluation and Adaptive Feedback

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The tennis serve is the only stroke that the athlete has full control over and is strongly associated with competitive performance. At the highest level, serve quality directly shapes point outcomes: during their 2019 French Open title runs, 73.8% of Nadal's service-game points won were after a first serve. Yet it is also a quick, multi-phase kinetic-chain motion linked to elevated shoulder loading and overuse injury risk. Nearly 24–50% of players experience shoulder pain from the serve, underscoring the biomechanical demands of it. Along with that, access to quantitative motion analysis to identify inefficiency and incorrect technique in the motion is limited by the high expense of using professional analysis instrumentation. Allowing structured feedback only in elite environments. However, motor learning research shows that immediate performance-specific feedback significantly improves the acquisition of complex motor skills. Leveraging this principle, my work presents an accessible biomechanics algorithm that converts user serve footage into stage-specific technique feedback using the Kovacs 3-phase, 8-stage serve model. The vision-based algorithm I developed processes serve video with MediaPipe to extract 33 body landmarks, constructs 3D motion traces, and from these keypoints, computes stage-linked kinematic variables, including knee and elbow flexion, trunk inclination, hip vertical displacement, and timing relationships across the serve. An elite reference model was constructed from professional serves processed through the same pipeline and used for comparison against the player. Testing showed that the system could consistently produce precise, actionable cues based on the exact inefficiencies in a player's serve technique.

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