



METHODS OF POSTURAL ASSESSMENT IN BADMINTON: A COMPARATIVE ANALYSIS OF CONVENTIONAL TECHNIQUES AND AI-POWERED POSE ESTIMATION

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Abstract: Player posture analysis presents significant challenges in sports performance evaluation and injury prevention, necessitating accurate and real-time detection systems. Traditional methods of posture analysis often rely on manual observation or post-game video review, which may not provide immediate insights or comprehensive movement data. Making use of OpenPose deep learning framework, this study proposes a methodology for real-time player pose detection and analysis. Initially, video footage is processed through OpenCV to extract individual frames, which are then analyzed using a pre-trained neural network to identify key anatomical landmarks and joint positions. Subsequently, computer vision techniques are employed to create skeletal representations of player postures, utilizing confidence thresholds to ensure detection accuracy. The resultant pose data is processed in real-time and can be integrated into various applications for sports analytics, rehabilitation monitoring, and performance optimization. This model enables coaches and medical professionals to receive immediate feedback on player movements, facilitating proactive injury prevention and technique improvement, thereby fostering more effective training environments for athletes at all levels.

Keywords: Pose Detection, Deep Learning, OpenPose, MoveNet

INTRODUCTION

Athletes depend on maintaining optimal body posture and executing proper movement patterns to enhance their overall performance and reduce the risk of injuries. The relationship between posture and movement is particularly significant in injury prevention, as improper alignment or inefficient movement mechanics can lead to increased strain on muscles and joints. This is especially relevant for amateur athletes who may not have access to professional training or biomechanical assessments, making them more susceptible to injuries. Research has consistently demonstrated that posture and movement quality are key factors influencing injury frequency, offering valuable insights into strategies for preventing sports-related injuries. By identifying and correcting postural imbalances, athletes can improve their movement efficiency, reduce unnecessary stress on the body, and minimize the likelihood of musculoskeletal issues over time.[1] Postural assessment is a fundamental component of understanding human biomechanics, as it helps in identifying musculoskeletal imbalances, movement inefficiencies, and areas of potential injury risk. Various methods have been developed to evaluate posture, ranging from traditional observational techniques used by healthcare professionals to advanced digital analysis tools that leverage technology for greater precision.

These assessments can provide critical data on spinal alignment, muscle symmetry, and joint positioning, enabling the development of targeted interventions for enhancing physical health and athletic performance. With the growing reliance on technology in postural analysis, there is an

increasing demand for standardized methodologies that ensure consistency, accuracy, and reliability in evaluations. [2] In recent years, posture analysis has emerged as a crucial research area in computer vision and artificial intelligence, leading to significant advancements in fields such as sports science, healthcare, rehabilitation, and human-computer interaction. AI-driven posture analysis has seen rapid progress due to the continuous improvement of machine learning algorithms, sensor technologies, and computational power, making it possible to analyse postural patterns with greater accuracy and efficiency. These advancements enable real-time posture monitoring, allowing for immediate feedback and correction, which is particularly beneficial for athletes, physical therapists, and researchers. Moreover, the ability to detect and interpret human and animal postures with high precision has expanded the applications of posture recognition beyond sports, contributing to innovations in medical diagnostics, ergonomic assessments, and interactive systems that enhance user experiences.

As AI-driven posture recognition continues to evolve, its integration with wearable sensors, computer vision tools, and deep learning models will further improve its capabilities, making it an indispensable tool for various domains.[3] These advancements underscore the growing significance of posture analysis and recognition in both sports and healthcare, demonstrating its potential to revolutionize injury prevention, performance optimization, and rehabilitation strategies. As technology continues to evolve, integrating AI-powered posture recognition with real-time biomechanical assessments will provide more precise and actionable insights for athletes, coaches, and medical professionals. Additionally,

the standardization of posture evaluation techniques will be crucial in ensuring consistency across different domains, from professional sports to clinical applications. By utilizing these innovations, individuals can proactively address postural imbalances, enhance movement efficiency, and reduce injury risks, ultimately promoting long-term musculoskeletal health and well-being.

LITERATURE SURVEY

The study of posture assessment has evolved significantly, integrating traditional methods with advanced AI-driven techniques to enhance accuracy, reliability, and real-time analysis. Poor movement patterns, which are detected by Functional Movement Screen (FMS), enhance risk of injury, whereas spinal misalignment causes musculoskeletal tension. Yet, studies on their combined effect are scarce. Postural assessment procedures vary, and PAS yields quantitative measures, whereas classic methods such as the Kendall method still hold clinical utility. Photogrammetry and digital photography add precision but demand precise calibration. Early posturing recognition used SIFT, HOG, and SVM, but deep learning with a focus on CNNs has significantly increased accuracy.

More sophisticated models and new trends such as transfer learning and graph neural networks continue to push AI-powered posture analysis. Pressure-based approaches to posture classification have become increasingly popular with their myriad applications in healthcare, rehabilitation, ergonomics, and human-computer interaction. These approaches employ pressure-sensitive matrices to assess posture, facilitating automated classification by machine learning algorithms. Fonseca *et al.* (2023) provided a systematic review, highlighting how machine learning algorithms, such as neural networks and traditional classifiers like Support Vector Machines (SVM) and k-Nearest Neighbors (kNN), have been used successfully in posture classification. Preprocessing methods, including Histogram of Oriented Gradients (HOG) and feature extraction algorithms, have been shown to improve classification accuracy notably, particularly when applied to high-dimensional pressure data. Deep learning techniques, such as Convolutional Neural Networks (CNNs) and autoencoders, have been shown to outperform other methods in posture classification, frequently achieving accuracy levels higher than 90% under training on large-scale, well-labeled datasets. The review also places emphasis on the importance of the quality and number of datasets, stating that whereas neural networks do well in compound classification problems, they need very large data in order to learn optimally. On the contrary, simpler algorithms like decision trees can still generate consistent results when trained on meager data. Future studies need to concentrate on improving pressure sensor designs to increase sensitivity and accuracy, incorporating real-time processing of data to enhance response, and the creation of hybrid models that integrate conventional machine learning with deep learning methods to achieve maximum accuracy as well as computational efficiency.[4] Postural assessment has made tremendous progress over the years with the incorporation of improvements that make measurements more accurate and reliable.

Classic measurement techniques, including visual observation and plumbline methods, were prevalent because of their simplicity and ease of use. These methods, however, did not possess the capability to offer accurate, quantifiable data, thus reducing their potential for intricate biomechanical analysis. Goniometry, with its provision of angle-based measurements, enhanced accuracy but raised issues of inter-rater reliability and consistency as a concern. Advances in technology resulted in the use of photographic and digitization techniques, allowing for more objective posture evaluation. Radiographic imaging subsequently became the gold standard because it could offer very precise skeletal alignment measurements, but radiation exposure issues limited its extensive application. Photogrammetric methods have recently become more prominent because they are non-invasive, simple to apply, and highly reliable in assessing postural variables.

Studies have shown that posture assessment is usually sport-specific, with marked differences found between athletes depending on the type of training and the pattern of movements. Research has indicated that sport-specific athletes, for example, in gymnastics and volleyball, have distinct postural features developed from the intensity of their training and biomechanical adjustments, emphasizing the importance of individualized assessment techniques.[5] Prior research has critically investigated postural differences among sport-specific athletes with various sports showing that repetitive training and sport-specific movements can contribute to long-term postural deviations or adaptations. Research has indicated that some high-intensity sports activities are responsible for spinal misalignments like kyphosis, lordosis, and scoliosis, and hence the need for frequent postural evaluation in sports training. High-precision measurement of spinal alignment has been made possible with advanced motion capture systems like the Zebris CMS-10 system, which offers important information on how sports training affects posture. These results highlight the importance of corrective exercises and customised training schemes for ensuring ideal postural positioning and avoiding musculoskeletal damage among athletes. There is a need for more future studies into the long-term effect of sports-specific training on posture and, specifically, an investigation into the applicability of future technologies, e.g., wearable sensors and AI-based motion analysis, into real-time assessment of posture with better injury prevention and performance gain. [6] Artificial intelligence-based posture analysis has revolutionized sports science and medicine through real-time, automatic evaluation. Deep learning models such as OpenPose and PoseNet employ convolutional neural networks (CNNs) to accurately identify major body landmarks and quantify movement patterns. Such techniques are highly accurate and scalable, well suited for posture monitoring, rehabilitation, and performance enhancement. Latest methods, including transformer-based architecture and reinforcement learning, further optimize posture classification and anomaly detection. AI integration in postural analysis offers real-time feedback, minimizing the risks of injury and enhancing training efficiency.

PROJECT DESCRIPTION

OpenPose is a deep learning framework designed for real-time multi-person pose estimation, capable of identifying key

skeletal points in images and video feeds. It utilizes a top-down approach[8], where the human body is first detected using a CNN-based target recognition network, which marks it within a rectangular bounding box. This bounding box is then used to locate the center of mass points for each detected individual. The same process is repeated for multiple individuals in the image, making the computational complexity directly dependent on the number of detected players. Previous research has emphasized the importance of movement assessment [7] in evaluating posture accuracy and identifying injury risks in sports performance.

The posture analysis[1] process using OpenPose follows a series of structured steps. First, a CNN-based network detects the players within an image or video and places them in bounding boxes. Once identified, the model localizes key skeletal points such as the shoulders, elbows, knees, and ankles. These detected points are then mapped onto a predefined skeletal structure, forming a complete human pose representation. Using this skeletal data, movement assessment is conducted to evaluate player form, technique, and deviations from optimal movement. Finally, the system provides feedback on posture accuracy, movement efficiency, and potential injury risks based on AI-driven analysis [1]. Studies have shown that poor posture and improper movement patterns can lead to increased injury risks among athletes, highlighting the importance of precise posture detection in sports training [1,5]. OpenPose has several advantages over other pose estimation models. One of its primary strengths is its ability to perform real-time multi-person detection without the need for additional hardware, making it highly accessible for training and gameplay analysis [7]. Unlike traditional sensor-based methods, which require wearable devices, OpenPose only relies on standard camera inputs. Additionally, its top-down approach improves accuracy by detecting body structure before keypoint localization[8] ensuring precise movement tracking. It is also highly scalable, efficiently handling multiple players in a single frame, whereas other models often struggle with occlusions and overlapping movements[6]. Moreover, OpenPose incorporates convolutional pose machines and stacked hourglass networks, enhancing its ability to capture complex body postures while mitigating gradient vanishing issues [8]. Its ability to deliver high-precision[4] posture tracking and real-time movement assessment makes it an ideal choice for badminton training, injury prevention and performance enhancement. Prior studies have emphasized the growing role of AI-based posture recognition[3] in sports training, rehabilitation and movement assessment, reinforcing the significance of OpenPose in this domain. PoseNet is a deep learning model unlike OpenPose which tracks multiple players, PoseNet focuses on single-person analysis. A spatial probability distribution refines these points,

ensuring precise pose estimation. This data is then used to assess movement quality, posture stability, and technique, providing real-time feedback for skill improvement and injury prevention [3,7]. While PoseNet excels in single-player analysis, it is less accurate in multi-person scenarios [8].

WORKING PRINCIPLE

The analysis process begins with **Video Preprocessing and Frame Extraction**, where frames are extracted from the input badminton match video at fixed intervals to enable detailed analysis of the player's movements over time. OpenCV is utilized for efficient frame extraction, followed by converting each frame into grayscale to reduce computational complexity. Gaussian blurring is applied to smooth out high-frequency noise while preserving essential structures. **Court Line detection** is performed using the Hough Transform to accurately localize player movements within the court. In the next phase, **Player Detection** using particle filtering is employed, a probabilistic tracking method that maintains a set of particles representing possible player locations, updating these particles based on visual information from each frame. This dynamic process ensures accurate player tracking, even when the player is occluded or moving rapidly. For detailed **Pose Detection**, OpenPose, a deep learning-based pose estimation tool, is utilized to detect and track key anatomical landmarks such as the head, shoulders, elbows, and knees. By analyzing the spatial relationships between these keypoints, OpenPose helps to estimate the connections between limbs and accurately track the player's posture throughout the match, offering insights into body alignment, balance, and movement efficiency. Following pose detection, feature extraction and motion analysis are carried out, computing joint angles, limb trajectories, and velocity vectors to analyze the player's motion dynamics, such as range of motion, movement direction, and speed. Canny edge detection refines boundary details, while the Hough Transform detects primary movement directions, providing a comprehensive understanding of stroke mechanics and footwork efficiency. The system incorporates a real-time feedback and visualization component through a graphical user interface (GUI), where detected motion features like joint angles and limb trajectories are displayed for easy interpretation. The system highlights posture errors and suggests biomechanical corrective measures, aiding players in improving their technique and minimizing injury risks. Additionally, pose and motion data are stored for long-term performance tracking, allowing players and coaches to compare performance across training sessions and enabling targeted interventions and informed decisions in training plans.

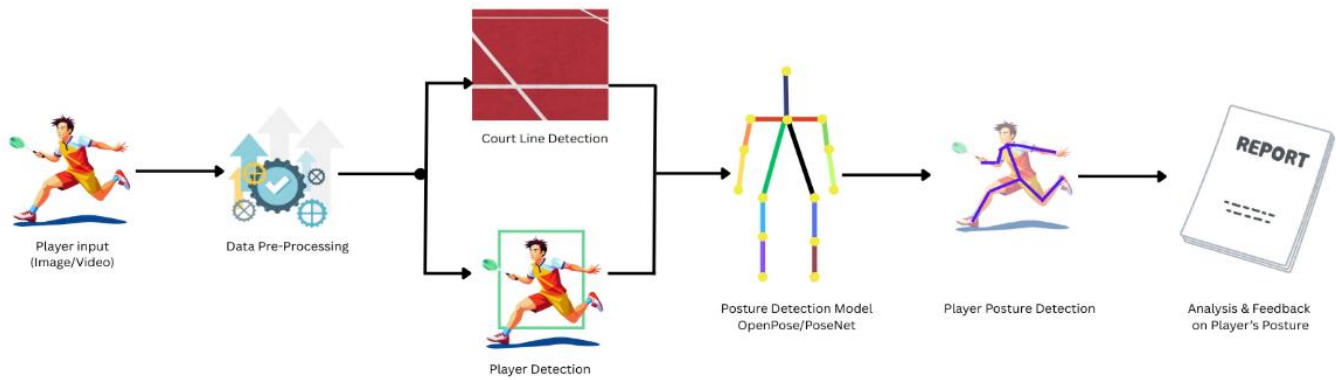


Figure 1 Architecture of the Proposed Model

RESULTS

COMPARISON	OPENPOSE	MOVENET
Inference Time Per Frame	2.96s	0.11s
Accuracy	90.00%	82.92%
Keypoints Considered	18	17

CONCLUSION

The OpenPose-based badminton pose detection system offers an advanced approach to tracking and analyzing player movements, leveraging deep learning to provide real-time skeletal keypoint estimations. By accurately detecting and mapping the positions of joints, the system effectively identifies critical postures such as serves, smashes, defensive stances, and footwork patterns, enabling a comprehensive understanding of player mechanics. One of the system's key strengths is its robustness under diverse conditions, maintaining high detection accuracy across varying lighting environments, camera angles, and player orientations, ensuring consistent performance in different settings. Additionally, by analyzing joint positions and movement trajectories, the system provides valuable insights into player technique, highlighting areas for improvement and facilitating more effective coaching and self-assessment. Overall, the integration of OpenPose into badminton pose detection enhances training efficiency, refines skill development, and serves as a powerful tool for performance optimization in both professional and amateur settings.

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