

Clinical Assessment of Adhesive Capsulitis Severity Using Transformer-Based Analysis of 3D Shoulder Motion

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Abstract:

Adhesive capsulitis (AC) is a musculoskeletal disorder causing pain, stiffness, and restricted shoulder motion. This study introduces Shoulder Geometric Pain Transformer (ShoulderGPT), a non-wearable, non-invasive deep learning framework for automatic AC severity classification using 3D shoulder kinematics from a single Azure Kinect depth camera. The proposed model combines Temporal Convolutional Networks (TCN) for fine-grained temporal dynamics and Transformer encoders for long-range dependency modeling across multiple movement cycles. A dataset of 157 participants performing four shoulder movements was analyzed. ShoulderGPT model achieved the highest performance metrics, with 97.54% accuracy, 97.23% F1-score, and 100% specificity, outperforming attention-based LSTM and GRU models. Attention visualizations highlighted clinically relevant motion cycles, supporting interpretability. The proposed framework offers a robust, explainable, and patient-friendly tool for automated AC severity assessment and clinical decision support.

Evaluation results of Attention-based GRU, LSTM, and TCN-Transformer models

Model	Acc	Precision	Specificity	Recall	F1-score
Att-GRU	92.27	93.52	100.00	93.36	93.24
Att-LSTM	94.38	95.02	100.00	95.15	95.00
TCN-Tr	94.54	95.23	100.00	95.19	95.60

Keywords:

Adhesive capsulitis, kinematic analysis, temporal convolutional networks, transformer encoder, shoulder rehabilitation monitoring.