

Lower Body Kinematics from Markerless Motion Capture Can Score and Discriminate Osteoarthritic Gait Across Severities

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INTRODUCTION: Objective functional assessment is a missing component in most orthopedic decision making. This is partly due to the technologies that can quantitatively capture joint motions not being unsuitable for clinical settings, requiring separate patient appointments and body-worn sensors, resulting in high patient burden. Recent advancements in computer vision and deep learning, however, have created markerless motion capture solutions that overcome many of these limitations, allowing detailed full body motion assessments to be performed as part of standard clinical examination. However, even with more accessible data capture it remains difficult to summarize and apply human motion data in everyday clinical practice. Therefore, the objective of this study is to determine if joint kinematics alone, as captured using a markerless motion capture, can be distilled into a single score and be used to discriminant severity of osteoarthritic gait.

METHODS: A dataset of 197 orthopaedic patients diagnosed with knee osteoarthritis (OA) in at least one leg were used for this analysis (severe OA, N=128; mild OA, N=16; moderate OA, N=53; age(mean(sd)) = 67(8); Females = 127; Males = 70). Diagnoses and severity of knee OA was determined by advanced care physiotherapists through clinical and radiographic examination. A dataset of 112 subjects well matched in age and sex (age(mean(sd)) = 68(10); Females = 72; Males = 40) with no known symptoms of knee OA were also included. The OA group underwent gait analysis directly following their clinical exam where full-body 3D kinematics were captured during 1 minute of overground self-selected walking using a markerless motion capture system (Theia3D, Theia Markerless Inc.). The Asymptomatic group underwent a similar gait analysis with data collection occurring at various locations around the community. All data were collected following approval by an Ethics Committee. Principal Component Analysis was used to extract the main patterns in the joint angles of the ankle, knee, and hip. Using only patients with severe knee OA and the Asymptomatic group, a linear discriminant analysis was used to build a linear scoring function that best separated the severe OA group from the Asymptomatic group. Recursive feature selection was used to retain only the joint angle patterns that best contributed to group separation. Five-fold cross-validation was used to estimate model performance. Using the scoring function, all subjects (severe, moderate, mild, and asymptomatic) were then given a single score summarizing their function. An ANOVA with pos-hoc comparisons (Tukey HSD) were used to test for severity effects. Group membership was also investigated by calculating which severity group each subject was closest to using z-scores.

RESULTS SECTION: The scoring function was able to correctly classify asymptomatic and severe knee OA individuals with a sensitivity of 85% and specificity of 92%. Twelve joint angle patterns of the ankle, knee and hip were found to best contribute to the scoring model. These patterns mostly captured the overall magnitude of the ankle, knee, and hip angles in all 3 planes (sagittal, frontal, and transverse). There was a significant effect of severity ($p < 0.001$), with the Asymptomatic group having higher scores than all OA groups (Figure 1.) The Severe OA had statistically significantly smaller scores than all OA groups ($p < 0.001$). No statistically significant difference was found between the mild and moderate OA groups. For the severe group, 65% scored as severe, with 22% closer to moderate, 9% to mild, and 6% to asymptomatic. For the moderate group, 51% scored as moderate, with 26% closer to severe, 13% to asymptomatic and 9% as mild.

DISCUSSION: A large sample of asymptomatic and knee OA patients was used to build and test a linear scoring function that was able to discriminant across OA severity. While there were differences in scores based on clinical ratings of severity, high variation was also observed in predicted scores. This highlights the additional information that can be obtained from objective functional assessments. Using only kinematic inputs from a markerless motion capture system makes this scoring workflow more accessible and applicable for real clinical spaces. Markerless motion capture allows for large and diverse samples of both patients and healthy individuals to be collected and is important to build scoring functions that can generalize well to unseen data. Future work should test the validity of this scoring framework in samples of orthopedic patients collected in multiple clinical centers and test the utility of such a score for following patients post intervention (i.e., total knee replacement).

SIGNIFICANCE/CLINICAL RELEVANCE: Kinematics alone measured with markerless motion capture can detect functional differences across clinical severity in those with knee osteoarthritis. A single continuous score can help capture current functional status, decline, and improvements longitudinally and be incorporated in standard clinical assessment to augment current clinical decision making.

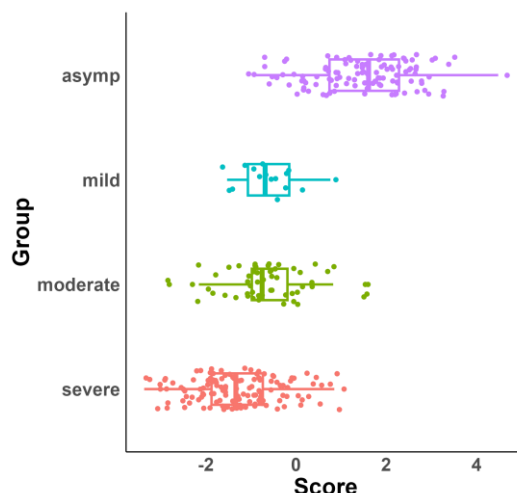


Figure 1. Linear Discriminant Scores for each subject by severity. Higher scores represent higher, more asymptomatic gait, and lower scores represent lower, more severe OA gait. Group boxplots and individual subject scatter are presented.