Evaluating the Effectiveness of Markerless Motion Capture to Quantify Lower Body Alignment to Distinguish Compartmental Knee Osteoarthritis

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INTRODUCTION: Lower extremity malalignment poses risks for the development of knee osteoarthritis (OA). Pre- and post-operative alignment has been shown to be an important predictor for knee arthroplasty success [1]. Alignment is typically calculated using the hip-knee-ankle angle (HKAA) from long-leg weight-bearing radiographs. Markerless motion capture is an evolving biomechanical assessment tool that uses commercially available video cameras, requires a low patient burden and involves no radiation exposure. While markerless motion capture can be used to quantify dynamic tasks, there is also potential to measure alignment during static tasks. The objective of this study was to evaluate the effectiveness of markerless motion capture to quantify lower body alignment to distinguish medial and lateral knee OA.

METHODS: Patients diagnosed with knee OA were recruited from an orthopaedic assessment clinic. Participants provided consent, as approved by the institutional ethics board. An orthopaedic surgeon classified patients as predominantly medial or predominantly lateral knee OA from existing short film radiographs. Equal medial and lateral OA cases were excluded. Lower limb alignment was assessed from a quiet standing trial. Subjects were instructed to stand upright and still with their feet facing forward (Figure 1) for thirty seconds. Participant clothing and position of upper extremities were not controlled during data collection. Markerless motion capture was performed using eight time-synchronized Sony Cameras (RX0-II) recorded at 60Hz and processed using commercial software Theia3D v.2023.01.0.3161 (Theia Markerless Inc., Kingston, ON) and Visual3D (C-Motion, Germantown, MD), providing estimated joint locations in three dimensions. The first five seconds of the standing trial was used for analysis to emulate the time required for a patient to obtain a weight-bearing radiograph. Hip, knee, and ankle joint positions were identified in the frontal plane and the HKAA (Figure 2) was calculated at each frame and averaged per patient. This study characterized HKAA as the angle between the vector hip joint centre to the knee joint centre and the knee joint centre to the ankle joint centre. Neutral alignment was defined as 180 degrees HKAA, varus alignment as greater than 180 degrees HKAA, and valgus alignment as less than 180 degrees HKAA. HKAA for medial and lateral groups were compared with an unpaired t-test using RStudio v4.3.1.

RESULTS: One hundred unique patients were classified as having predominantly medial or lateral knee OA. Nine subjects were excluded due to unsuitable clothing (skirts below the knee) posing tracking difficulty or wearing assistive devices such as a knee brace. Ninety-one subjects (31 male / 60 female) with a mean age of 67 (SD 9) years were analyzed, of which 82 were classified as having medial OA and 9 with lateral OA. Subjects with medial OA had statistically significantly higher HKAA (mean = 183 degrees, SD = 3.4), than those with lateral OA (mean = 177 degrees, SD = 2.7, p <0.001, Figure 3).

DISCUSSION: We found that most patients diagnosed with predominantly medial OA exhibit varus alignment (bow-legged), while most patients with predominantly lateral OA exhibit valgus alignment (knock-kneed) with statistically significant alignment differences between groups. These findings are consistent with previous literature, as patients diagnosed with medial OA tend to demonstrate varus alignment, whilst patients with lateral OA exhibit valgus alignment [2]. Some limitations to this work include the exclusion of patients exhibiting patellofemoral OA in conjunction with their medial or lateral diagnosis, as some patients have multicompartmental knee OA. Further, other markerless systems may yield different results due to different training datasets. This study shows the quantitative distinction markerless motion capture exhibits between compartmental knee OA in an osteoarthritic population. In turn, this novel technology shows promise in its ability to be used by healthcare practitioners to obtain lower-limb alignment data to set realignment targets via either rehabilitation programs or surgical intervention.

SIGNIFICANCE/CLINICAL RELEVANCE: Quantifying HKA alignment using markerless motion capture can provide an alternative, radiation-free, diagnostic tool for medical practitioners to gain insight into a patient's lower limb alignment as part of an orthopaedic assessment.

REFERENCES: [1] P. Choudhury *et al.*, "Radiologists should use the hip-knee-ankle angle rather than the mechanical axis deviation to describe knee alignment," *Skeletal Radiol.*, vol. 52, no. 6, pp. 1159–1167, Jun. 2023. [2] L. Sharma *et al.*, "Varus and valgus alignment and incident and progressive knee osteoarthritis," *Ann. Rheum. Dis.*, vol. 69, no. 11, pp. 1940–1945, Nov. 2010.
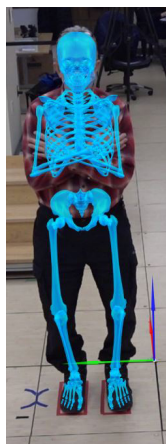

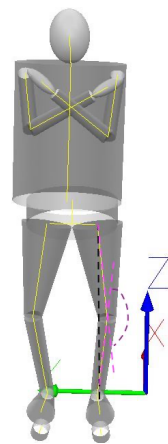Figure 1: Orthopaedic patient performing the standing task for markerless motion capture

Figure 2: HKAA convention used for this study shows angles greater than 180º (pink line) being associated with a bow-legged (varus) alignment
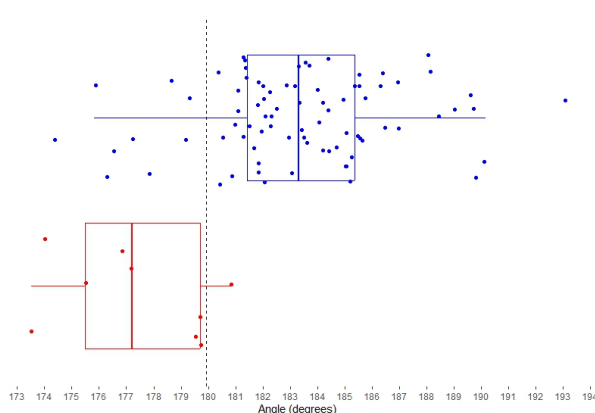

Figure 3: Hip-Knee-Ankle Angle measurements for patients with predominantly medial OA (blue) and predominantly lateral OA (red). Neutral alignment (black dotted line) is defined as 180º. The plot illustrates the median, interquartile range, and the upper and lower limits which are set at 1.5 times the interquartile range beyond the first and third quartiles