Markerless Motion Capture Enables a Future for Multicentre Orthopaedic Trials

Jereme Outerleys[1,2], Elise Laende[1,3], Monica Malek[4], Stephanie Civiero[5], Kim Madden[4], Matthew Ruder[6], Anthony Adili[4], Dylan Kobsar[6], Janie Wilson[5], Kevin Deluzio[1]

[1]Smith Engineering, Queen's University, Kingston, Canada [2]Theia, Kingston, Canada [3]Designs System Engineering, University of Waterloo, Waterloo, Canada [4]Department of Surgery, Research Institute of St. Joe's, Hamilton, Canada [5]School of Biomedical Engineering, Dalhousie University, Halifax, Canada [6]Department of Kinesiology, McMaster University, Hamilton, Canada

Email: jereme.outerleys@queensu.ca

Summary

Markerless motion capture can standardize biomechanical data collection across multiple clinical centres, addressing challenges with traditional technologies. This study analyzed gait biomechanics in 486 participants across 3 centres including individuals with and without knee osteoarthritis (OA), identifying gait deviations in individuals with severe OA. Our findings establish the viability of multicentre human motion trials, paving the way for large-scale orthopaedic biomechanics research.

Introduction

Objective biomechanical outcomes have seen limited adoption in orthopaedics due to challenges in clinical integration, as traditional motion capture is time-intensive and difficult to standardize. Adoption is further hindered by a lack of established clinical efficacy, with previous work limited by small sample sizes and the inability to pool data across centres. Markerless motion capture offers a practical solution to standardized biomechanical data collection in clinical settings. This work aimed to demonstrate the potential of multicentre trials using markerless motion capture by assessing gait biomechanics from multiple centres in an OA population.

Methods

Data were collected on independent cohorts of patients with severe knee OA and asymptomatic participants at three centres (C1, C2, C3) using aligned protocols. All centres used the same model of video camera (RX02, Sony, 60 Hz) with number and placement based on location constraints. Overground walking trials at self-selected speeds were performed and analyzed with Theia3D (v2023.1.0.3161, Theia). C3D files were transferred to a centralized storage cluster for further processing using a single, standardized processing pipeline (SIFT/Visual3D, HAS-Motion Inc.) to obtain lower limb kinematics and temporal distance metrics. Principal component analysis was used to investigate feature differences in joint angles of the hip, knee and ankle in the sagittal plane as well as the frontal plane of the knee. Two-factor ANOVAs tested for centre and group (OA vs asymptomatic) differences (α=0.05).

Results and Discussion

Across all centres, 486 participants were included: 351 with knee OA and 135 asymptomatic individuals, with the OA cohorts well matched in both age and sex (Table 1). Gait waveforms showed strong visual agreement (Figure 1), with some centre-specific variations in select joint angles features. Consistent differences between OA and asymptomatic groups were observed across all temporal distance metrics and 9 of 10 joint angle PCs. The OA group exhibited established biomechanical markers of OA [1], including slower walking speed, lower range of motion at the hip, knee, and ankle, and higher knee adduction. The ability to detect gait deviations in a large cohort pooled from multiple centres supports the validity and scalability of markerless motion capture for broad clinical applications.

Table 1. Mean (SD) demographics by group and centre.

	Asymptomatic			OA		
	C1	**C2**	**C3**	**C1**	**C2**	**C3**
N	36	58	41	70	166	115
Age (years)	33.9 (8.9)	58.9 (19.1)	35.7 (15.3)	66.0 (9.1)	67.4 (8.6)	65.9 (9.4)
Male (%)	47%	52%	51%	38%	43%	37%
Speed (m/sec)	1.40 (0.12)	1.33 (0.15)	1.32 (0.20)	0.98 (0.18)	0.97 (0.20)	0.90 (0.21)

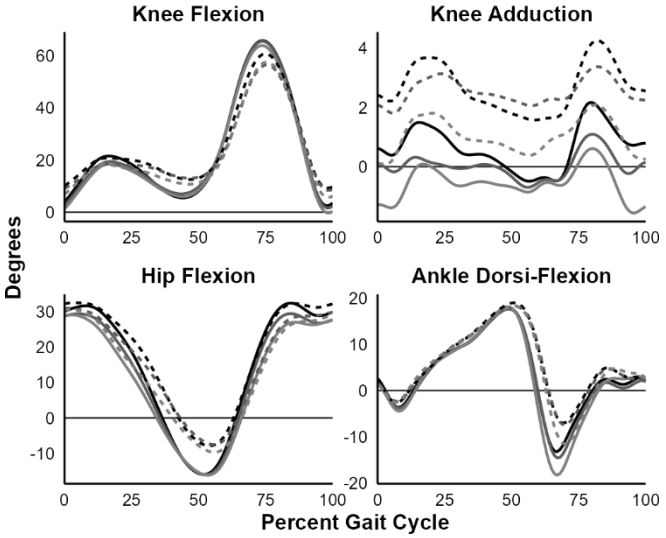

Figure 1. Ensemble average gait waveforms (solid line = asymptomatic, dashed = OA; color = centres).

Conclusions

Through the successful implementation of markerless motion capture across multiple clinical centres, we demonstrated the feasibility of conducting multicentre trials, supporting the potential for large-scale orthopedic applications.

References

[1] Astephen et al. (2008). *J Orthop Res*, **26**:3;332-341.