Comparison of shoulder kinematics between Theia 3D markerless and marker-based motion capture

Eleonora Croci[1,2], Christoph Künzel[1,2], Andreas Marc Müller[1,2], Annegret Mündermann[1,2,3,4]
[1]Department of Biomedical Engineering, University of Basel, Basel, Switzerland
[2]Department of Orthopaedics and Traumatology, University Hospital Basel, Basel, Switzerland
[3]Department of Clinical Research, University of Basel, Basel, Switzerland
[4]Schulthess Clinic Zurich, Zurich, Switzerland
Email: eleonora.croci@unibas.ch

Summary

Shoulder kinematics in 20 healthy subjects were measured during full arm ranges of motion (ROM) simultaneously with a marker-based (Qualisys) and a markerless (Theia 3D) motion capture system and compared. Similar kinematic patterns were observed with generally good agreement for abduction and flexion angles but larger variations for the external rotation angles. Some improvements still need to be made to Theia 3D for shoulder kinematics, especially for external rotation angles and above shoulder tasks.

Introduction

Shoulder kinematic analysis during full arm ROM can provide information about functional impairment and be used to monitor rehabilitation progress. The current gold standard for non-invasive and non-radiation measurements is marker-based motion capture, but its applicability in clinical settings is limited due to long preparation and post-processing times. Markerless motion capture, e.g. Theia 3D [1], overcomes these limitations, but it is still unclear how it performs for shoulder kinematics compared to marker-based motion capture. We aimed to compare shoulder kinematics during full arm ROM between markerless (Theia 3D) and marker-based motion capture systems in healthy subjects.

Methods

Overall, 20 healthy subjects (10 men and 10 women; mean ± standard deviation; age: 26.5 ± 2.0 years, body mass index: 23.2 ± 1.9 kg/m^2) participated in this study. Synchronized markerless (Theia 3D, v2023.1) and marker-based (Qualisys) motion capture data were collected during three repetitions of bilateral full arm scaption, abduction, flexion, internal rotation, external rotation, and internal and external rotation at 90° abduction while seated. Reflective markers were placed on landmarks of the upper extremities and torso according to the International Society of Biomechanics (ISB) guidelines [2]. Marker-based glenohumeral joint centers were estimated using the regression equation outlined by the International Shoulder Group [3] on a static trial. Data were filtered with a low pass Butterworth filter with a 6 Hz cut-off frequency. Rotation matrices from Theia 3D were adjusted to match the ISB coordinate system. Kinematics were reconstructed using the X-Z-Y sequence for all movements, apart from full flexion for which the Z-X-Y sequence was used [4]. All data were processed in MATLAB R2023b. Coefficients of multiple correlation (CMCs) and root mean square errors (RMSEs) were calculated for each angle and movement task based on the average waveforms of all shoulders.

Results and Discussion

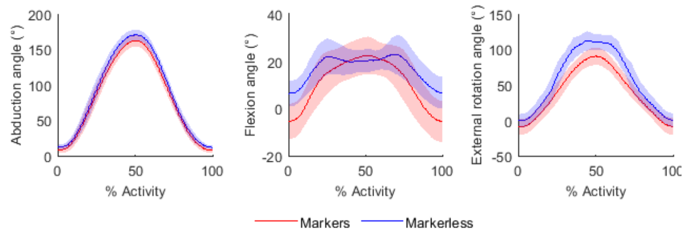

Figure 1: Kinematic trajectories of the scaption movement.

Overall, markerless and marker-based trajectories had similar patterns, with generally larger differences towards the turning point of the movements (Figure 1). RMSEs were smallest for the abduction angle and largest for the external rotation angle. CMC was mostly good to excellent (>0.75), but CMC was moderate (0.65-0.75) for flexion angles during abduction and rotation at 90° and for abduction angles during flexion and weak (<0.65) for flexion angles during external rotation (Table 1).

Table 1: Root mean square error (RMSE) and correlation of multiple coefficients (CMC) for all angles and movement tasks

Movement task	**Abduction angles**		**Flexion angles**		**External rotation angles**	
	RMSE	CMC	RMSE	CMC	RMSE	CMC
Scaption	8.6°	0.994	9.3°	0.767	24.5°	0.902
Abduction	8.1°	0.995	9.9°	0.732	25.8°	0.873
Flexion	6.4°	0.683	11.5°	0.992	16.8°	0.869
Int. rotation	5.6°	0.969	11.9°	0.768	18.9°	0.801
Ext. rotation	3.0°	0.823	9.7°	0.319	19.7°	0.869
Rot. at 90°	4.1°	0.824	9.3°	0.663	16.4°	0.967

Conclusions

Theia 3D captured overall kinematic patterns similar to those of the marker-based system, highlighting its potential for clinical applications, particularly in situations where identifying movement patterns is critical. However, the level of agreement between the two systems varies depending on the movement performed and the specific angle of interest, particularly for external rotation angles. Assessment of shoulder kinematics with Theia 3D seems promising but some improvements are still needed.

References

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