How Accurately Can We Quantify Hip Joint Angles with Motion Analysis and the Euler/Cardan Angles?

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Introduction and Objective

The Euler/Cardan angles are a mathematical approach commonly used to quantify human three-dimensional joint rotations (1).

- Possible combinations include ‘XYZ’, ‘XZY’, ‘YXZ’, ‘YZX’, ‘ZYX’, and ‘ZXY’
- Crosstalk creates error that increases as the rotation about the second sequenced axis increases (1, 2).

The objective of this research was to determine which Euler/Cardan angles are accurate for representing joint rotation angles compared to measured values from a physical model.

- The physical model used for this project is an updated model from a previous study in the same lab (2).

Methods

A physical model of the right hip joint was created that could be placed in known combinations of flexion/extension, adduction/abduction, medial/lateral rotation.

- The proximal (pelvis) and distal (thigh) segments were defined using retroreflective markers
- These markers were captured by 8 optoelectronic cameras recording at 200 Hz for 1 second.

There are 165 total possible combinations of the following angles

- 0˚, 15˚, 30˚, 45˚, 60˚, 75˚, 90˚, 105˚, 120˚, 135˚, 150˚ of flexion (X-axis),
- -30˚, 0˚, and 30˚ of adduction-abduction (Y-axis),
- -45˚, -30˚, 0˚, 30˚, and 45˚ of lateral rotation-medial rotation (Z-axis)

Marker data were labelled in Qualisys Track Manager and processed in Visual 3D

The Euler/Cardan angles were calculated for each rotation segment with both the proximal and distal segments as the reference segment.

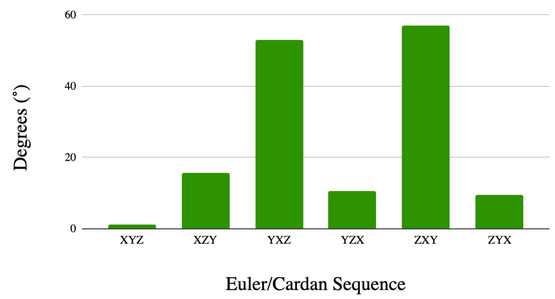
- The root mean square error (RMSE) between the calculated and measured hip joint angles was determined to compare the 6 Euler/Cardan sequences.

Results

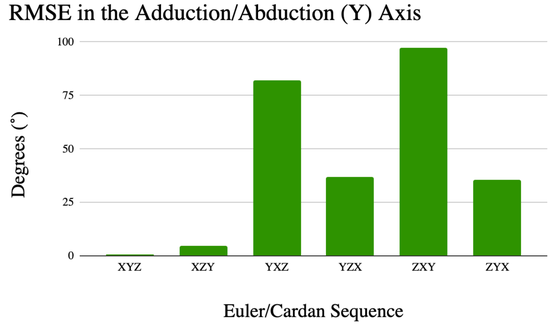
With the proximal segment as the reference, the ‘XYZ’ sequence was the most accurate (RMSE X = 1.1˚, RMSE Y = 0.7˚, RMSE Z = 0.9˚). With the distal segment as the reference, the ‘ZYX’ sequence was the most accurate with the same RMSE.

- Other Euler/Cardan sequences resulted in larger errors ranging from = 4.6˚- 104.7˚.

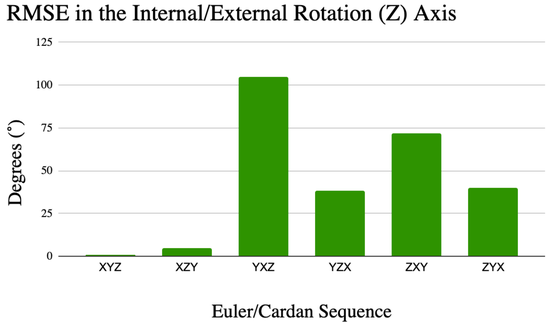
RMSE in the Flexion/Extension (X) Axis



RMSE in the Adduction/Abduction (Y) Axis



RMSE in the Internal/External Rotation (Z) Axis



Conclusion

Due to crosstalk, the second axis in the rotation sequence must be the adduction/abduction axis to minimize error as it has the smallest magnitude Either the ‘XYZ’ (with the proximal segment as reference) or ‘ZYX’ (with the distal segment as reference) Euler-Cardan sequences should be used for biomechanical analyses

- These are the most accurate compared to a physical model representing hip joint rotations.

Acknowledgements

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References

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2. Dæhlin, T. E. and Chiu, L.Z.F. (2019). *A physical model to quantify error in determining hip joint angles using Euler/Cardan angles.* Conference proceedings: International Society of Biomechanics Conference, Calgary, AB, Canada, 2019.