PERFORMANCE OF THE KINEMATICALLY CONSTRAINED METHOD FOR JOINT PARAMETER ESTIMATION

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Summary

The Kinematically Constrained (KC) method for calculating joint parameters (centers and axes of rotation) is evaluated. Kinematic variables related to accuracy are compared for the KC method and the standard method.

Conclusions

The KC method outperforms the standard method for calculating joint parameters.

INTRODUCTION

Joint parameters (centers and axes of rotation) are fundamental elements of gait analysis. Joint parameters derived using the standard approach (regression equations, knee alignment device) contain significant errors. The most prominent alternative approach, called the "functional method", defines the hip center from a sphere that best fits the motion of thigh markers relative to the pelvis [1]. Recent studies suggest that the functional method's variability may be unacceptably large for clinical gait analysis [2]. The functional method is also limited by its restriction to spherical joints. A new approach for estimating joint parameters, called the KC method, has recently been developed and shown to be objective and repeatable [3,4]. The KC method uses a repeated application of kinematic constraints derived from the topology of interconnected bodies. To date, the method's accuracy has not been directly assessed *via* high resolution, calibrated, three-dimensional imaging data (e.g. MRI, RSA). In this study, we summarize several indirect measures of accuracy.

MATERIALS AND METHODS

Four different therapists tested the same subject on different days. Lower extremity kinematics were derived using both KC-based and standard joint parameters (VCM 1.34, Vicon Motion Systems, Oxford, UK). Summary variables were calculated and compared for the two methods.

RESULTS

Table 1: Results from the repeated measures experiment.

Measure	Rationale	Result
Hip Center to Knee Marker distance	An accurate hip center reduces changes in leg length	Δ(KC) = 15.8 mm Δ(REGR) = 21.0 mm $p = 0.05$
Knee Varus/Valgus Range of Motion (ROM)	An accurate knee flexion axis minimizes the Var/Val ROM that results from "cross-talk" between axes.	ROM(KC) = 11.9º ROM(KAD) = 16.6º $p < 0.001$
Knee Varus/Valgus and Knee Flexion/Extension coupling	An accurate knee flexion axis de-couples the coronal and sagittal plane angles	Mean ρ(KC) = 0.30 Mean ρ(KAD) = 0.46 Max ρ(KC) = 0.46 Max ρ(KAD) = 0.88
Knee Flexion/Extension ROM	An accurate knee flexion axis maximize knee flexion/extension ROM	ROM(KC) = 71.1º ROM(KAD) = 63.1º $p < 0.001$

DISCUSSION

It has previously been established that joint parameters derived using the KC method are repeatable and objective [3,4]. By summarizing different elements of a repeated measures study, a body of evidence has been presented suggesting that the KC method is also accurate. Other less direct measures of accuracy have also been checked with equally promising results. These include the proximity of the hip center to the regression-based values, the proximity of the knee center to the mid-condylar point and the orientation of the knee axis relative to the bi-condylar axis. This study is not conclusive due to its circumstantial nature. However, the results provide ample motivation and rationale for direct validation studies that would yield rigorous accuracy assessment.

REFERENCES

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