A UNIFYING APPROACH FOR THE STANDARDISATION OF KINEMATIC SIGNALS

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Introduction

In clinical movement biomechanics, kinematic data are processed into representative time-series signals that characterise the motion of body joints. Exacerbated by a lack of consensus around joint coordinate frame definitions, the influence of local segment frame alignment on the characteristics of these signals has proven to be a major limitation [1,2]. For consistent interpretation of joint motion to be possible, differences in frame definition must first be addressed. Building on a previously introduced Frame Orientation Optimisation Method (FOOM) [2], we present and assess a REference FRame Alignment MEthod (REFRAME), exploring its ability to induce convergence towards a consistent set of knee kinematic signals in all six degrees-of-freedom.

Methods

REFRAME employs a self-contained optimisation approach to re-align local segment reference frames such that the resultant joint kinematics fulfil certain user-defined criteria. Here, an implementation of REFRAME based on the combined use of nonlinear and global optimisation algorithms is validated using *in vivo* knee kinematics captured using a moving videofluoroscope [3]. Different local femoral reference frames were defined based on three distinct methods of estimating the primary joint axis (cylindrical: CA, functional flexion: FFA, and transepicondylar: TEA) to derive flexion/extension, ab/adduction and int/external rotation, as well as anteroposterior, mediolateral and proximodistal translations over five stair descent trials [4]. The resulting kinematic signals associated with each of the approaches were optimised, using REFRAME to target minimum root-mean-square error (RMSE) vs. 0 for ab/adduction and int/external rotation, as well as minimum variance for anteroposterior (AP), mediolateral (ML) and proximodistal (PD) translation.

Results

Implementation of REFRAME realigned local segment frames to result in fundamental changes of the magnitude and characteristics of kinematic signals. This led to a reduction in peak RMSEs from 8.32 mm ± 0.05 mm (PD of FFA vs. TEA) and 6.15° ± 0.05° (int/ext. rot. of CA vs. TEA) to a maximum of 0.47 mm ± 0.08 mm (AP of FFA vs. TEA) and 0.20° ± 0.17° (flex/extension of CA vs. TEA), as well as evident convergence of most kinematic signals (Fig. 1).

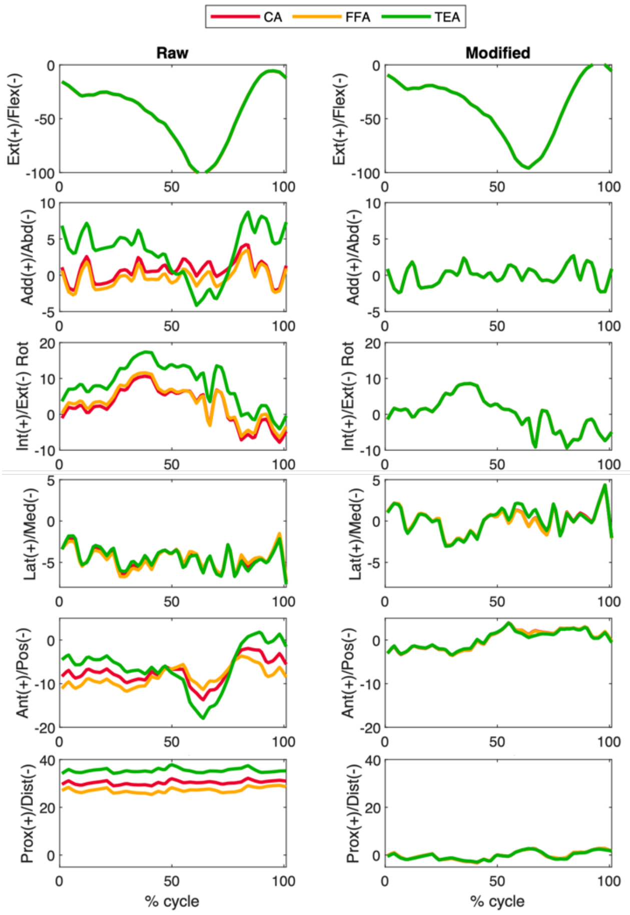

Figure 1: Knee kinematics (rotations [°]: tibia relative to femur; translations [mm]: femur relative to tibia) during a sample stair descent trial, using three different primary axes, before (raw) and after (modified) REFRAME. (CA and FFA partially covered by TEA)

Discussion

REFRAME demonstrated the ability to optimise the orientation and position of local segment frames, leading to sufficient changes to allow convergence of kinematic signals that were initially derived using different methods of primary axis definition. This standardisation protocol therefore holds the potential to enable consistent interpretation and comparison of joint kinematics derived using different approaches.

References

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