APPLICATION OF DIFFERENT OPTIMISATION CRITERIA TO STANDARDISE KINEMATIC SIGNALS

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Introduction

In motion analysis, kinematic signals are calculated from captured data points to allow the clinical interpretation of the underlying movement patterns of body joints. Although assessment of kinematic signals should inherently lead to a consistent interpretation of joint movement, regardless of the numerical approach used to derive them, this has proven not to be the case [1,2]. The recently presented Frame Orientation Optimisation Method (FOOM) [3] and REference FRame Alignment MEthod (REFRAME) aim to realign local segment frames based on the numerical optimisation of specific criteria to allow convergence of different kinematic signals that represent the same underlying movement. Here, we validate and explore the use of distinct optimisation criteria on the characteristics of the resulting kinematic signals.

Methods

REFRAME reorientates and repositions femoral and tibial reference frames to optimise the values of user-selected criteria. Here, we assess the ability of REFRAME implementations based on different objective criteria to allow signal convergence and thus consistent interpretation of rotational knee kinematics. Previously captured *in vivo*, kinematic data from a moving videofluoroscope were processed by defining three different flexion/extension axes (cylindrical: CA, functional flexion: FFA, and transepicodylar: TEA), as well as the associated three-dimensional (3D) local femoral frames [4]. Flexion/extension, ab/adduction and int/external rotation according to these frames were determined during stair descent for a healthy subject. The resulting rotations were optimised by using REFRAME to target out-of-sagittal plane rotations based on one of five statistical parameters (root-mean-square error, sum of absolute values, variance, maximum absolute value, and range of motion over an activity cycle).

Results

The use of different methods to define a primary joint axis led to clearly distinct (raw) kinematic signals. Implementation of REFRAME repeatedly achieved signal convergence, regardless of the statistical parameter selected. However, the use of different parameters was shown to influence the characteristics of the resultant optimised signals to certain degree (Fig. 1).

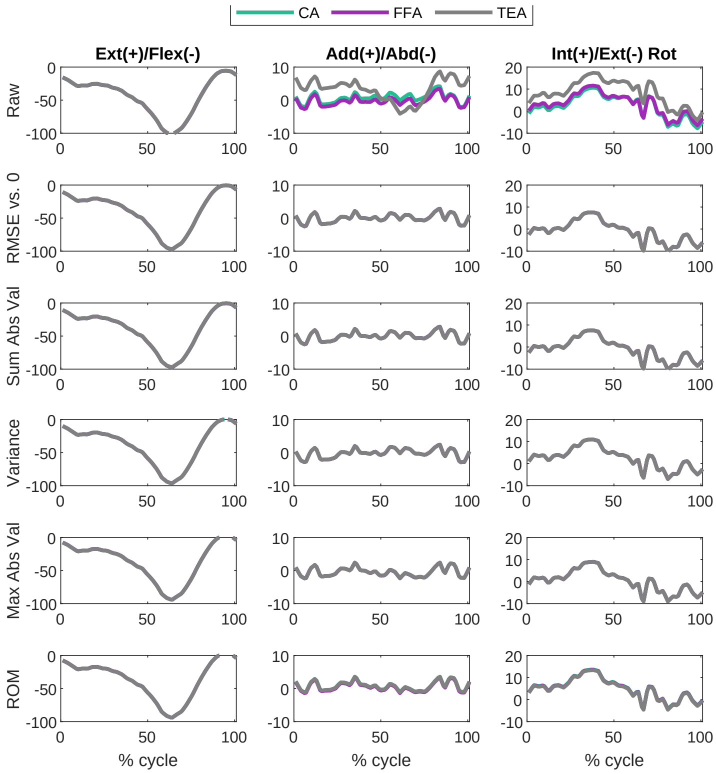

Figure 1: Knee kinematics [°] (tibia relative to femur) for a sample subject stair descent trial before (raw) and after REFRAME implementations with different objective criteria. (CA and FFA covered by TEA in subplot 1 and rows 2-6).

Discussion

Five different REFRAME implementations (based on five different statistical parameters) successfully demonstrated their ability to allow convergence of kinematic signals derived using different methods but originating from a common movement. The choice of optimisation parameter(s) should be methodically selected to specifically address an underlying research question. REFRAME thus offers the flexibility to select from a variety of objective criteria, while consistently allowing a repeatable and valuable representation of joint kinematics.

References

1. Postolka et al, J Biomech, 144:111306, 2022.
2. Sauer et al, Materials, 14(24), 7644, 2021.
3. Ortigas Vásquez et al, in review, 2023.
4. Postolka et al, J Biomech, 110:109915, 2020.