Repeatability of three-dimensional knee kinematics across different marker set protocols during walking

Reginaldo Fukuchi, Raíssa Thibes, Haron Dorta, Claudiane Fukuchi, Marcos Duarte

Laboratório de Biomecânica e Controle Motor, UFABC (http://demotu.org/)
e-mail: reginaldo.fukuchi@ufabc.edu.br

Introduction: Clinical gait analysis (CGA) has become a popular tool for examining different populations. Several marker set protocols have been used in CGA either employing direct kinematics, such as hierarchical and six degrees-of-freedom models (6DOF), or inverse kinematics (IK) in gait simulation studies [1,2]. In fact, the hierarchical models have been far more popular compared to 6DOF or IK models partly due to the fact that it is more simplistic and well documented [1]. However, the chosen marker protocol has to present acceptable repeatability to provide reliable CGA outcomes. Therefore, the aim of this study was to present preliminary results of an ongoing study comparing the repeatability of the three-dimensional (3D) joint angles of a hierarchical, 6DOF and IK model during treadmill walking.
Methods: 3D marker coordinates of a male subject (age: 37 years; height: 176 cm; mass: 103 kg) were collected by a 12-camera motion capture system (Motion Analysis Corp.) while he walked on an instrumented treadmill (Bertec Inc.) at 1.2 m/s. The kinematics data were recorded for 30 seconds at 150 Hz after an accommodation period of 3 minutes. The following marker set protocols were examined simultaneously to represent each kinematic model type: Helen-Hayes (HH) (hierarchical), Calibrated Anatomical System Technique (CAST) and an IK model. The full description of these models, including the definition of the anatomical segment reference systems, can be found elsewhere [1]. The models were defined using 3D markers coordinates during a standing anatomical calibration trial. The models were then applied to the walking kinematics data and 3D knee angles were calculated using ZXY Cardan rotation sequence in Visual 3D software (C-motion Inc.). The IK model assumed the knee was a 1DOF hinge joint. To measure the repeatability of the models, we calculated the mean of the standard deviation across each percentage of the gait cycle of 29 strides.

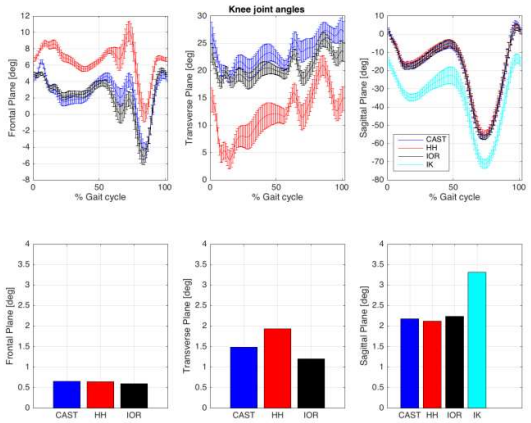

Figure 1. Mean (SD) time-series curves of the right knee angle during treadmill walking at 1.2 m/s (top). Average precision of the knee angle in different marker models (bottom).

Results: The 3D knee angle curves are displayed in Figure 1. Overall the curves exhibit similar patterns. However, the IK model and the HH model displayed a systematic shift compared to the other models at the sagittal and non-sagittal planes, respectively. In terms of precision, the IOR model seems to perform best at both the frontal and transverse but not at the sagittal plane compared to CAST and HH. Conversely, the HH and IK model performed the worst at the transverse and sagittal planes, respectively.
Conclusion: The results of this preliminary study indicate that the HH model presents comparable precision relative to more complex models, particularly at the sagittal and frontal planes knee angles, challenging the idea that a more complex model might result in a more reliable CGA.

References: [1] Baker R. Measuring Walking. Mac Keith Press 2013.
[2] Kainz H, et al. Reliability of four models for clinical gait analysis. GP 2017;54:325-331.