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The conventional gait model, an open-source implementation that reproduces the past but prepares for the future

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ABSTRACT

Background: The Conventional Gait Model (CGM), known by a variety of different names, is widely used in clinical gait analysis. We present pyCGM2, an open-source implementation of the CGM with two versions. The first, CGM1.0, is a clone of Vicon Plug In Gait (PiG) with all its variants. CGM1.0 provides a platform to test the effect of modifications to the CGM on data collected and processed retrospectively or to provide backward compatibility. The second version, CGM1.1, offers some practical modifications and includes three well documented improvements.
Research question: How do improvements of the conventional gait model affect joint kinematics and kinetics?
Method: The practical modifications include the possibility to use a medial knee epicondyle marker, during static calibration only, to define the medio-lateral axis of the femur in place of the knee alignment device. The three improvements correspond to the change of pelvis angle decomposition sequence, the adoption of a single tibia coordinate system, and the default decomposition of the joint moments in the joint coordinate system. We validated the outputs of version CGM1.0 against Vicon-PiG, and estimated the effect of the modifications included in version CGM1.1 using gait data collected in 16 healthy participants.
Results: Kinematics and kinetics of CGM1.0 were superimposed with that of Vicon-PiG, with root mean square differences less than 0.04° for kinematics and less than 0.05 N.m.kg-1 for kinetics.
Significance: The differences between the CGM1.1 and CGM1.0 were minimal in the healthy participant cohort but we discussed the expected difference in participants with different gait pathologies. We hope that the pyCGM2 will facilitate the systematic testing and the use of improved processing methods for the conventional gait model.

1. Introduction

The Conventional Gait Model (CGM) is the predominant biomechanical model used in clinical gait analysis [1]. Originating in the 1970's and developed by various individuals [1,2], the strengths associated with the CGM include being understandable by a large community, even non-experts in Biomechanics [1]. The CGM became popular because it was distributed as a package (first Vicon Clinical Manager, then Plug in Gait) within the Vicon (Oxford Metrics, UK) clinical motion capture software.

Extensive application of the CGM in clinics and medical research [2,3] have exposed the model to criticism. For example, the lack of accuracy in positioning the thigh and shank segment wand-mounted markers has been responsible for large errors in the definition of the coronal planes for these segments [4,5]. The Knee Alignment Device (KAD) [6] was introduced to reduce these errors, by improving the location of the Knee Joint Centre (KJC) and the alignment of the medio-lateral axis of the femur with the trans-epicondylar axis. However, use of the KAD may be outdated now that most clinical gait analysis systems have resolutions sufficient to capture a small (i.e. < 9 mm in diameter) additional reflective marker on the medial femoral epicondyle.

Similarly, the clinical relevance of CGM outputs may benefit from research that has been published since its inception but have not been implemented yet. For example, Baker et al. [7] demonstrated that the CGM's angular decomposition does not correspond to the clinical definition of the terms for the pelvis. Pelvis tilt is defined clinically as the rotation of the pelvis around its medio-lateral axis, but it is calculated by the CGM as the rotation around the medio-lateral axis of the laboratory's coordinate system.

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