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Review

Human movement analysis using stereophotogrammetry Part 4: assessment of anatomical landmark misplacement and its effects on joint kinematics

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Abstract

Estimating the effects of different sources of error on joint kinematics is crucial for assessing the reliability of human movement analysis. The goal of the present paper is to review the different approaches dealing with joint kinematics sensitivity to rotation axes and the precision of anatomical landmark determination. Consistent with the previous papers in this series, the review is limited to studies performed with video-based stereophotogrammetric systems. Initially, studies dealing with estimates of precision in determining the location of both palpable and internal anatomical landmarks are reviewed. Next, the effects of anatomical landmark position uncertainty on anatomical frames are shown. Then, methods reported in the literature for estimating error propagation from anatomical axes location to joint kinematics are described. Interestingly, studies carried out using different approaches reported a common conclusion: when joint rotations occur mainly in a single plane, minor rotations out of this plane are strongly affected by errors introduced at the anatomical landmark identification level and are prone to misinterpretation. Finally, attempts at reducing joint kinematics errors due to anatomical landmark position uncertainty are reported. Given the relevance of this source of errors in the determination of joint kinematics, it is the authors' opinion that further efforts should be made in improving the reliability of the joint axes determination.

Keywords: Stereophotogrammetry; Human movement; Anatomical landmark; Joint kinematics

1. Introduction

Human movement analysis using stereophotogrammetric measurements and rigid body modelling requires the definition of systems of axes associated with each bony segment incorporated in the model. The systems of axes defined from body-surface marker positions are referred to here as marker cluster technical frames (CTF), while those defined from anatomical landmark (AL) positions are referred to as anatomical frames (AF). The differences of the features of the CTFs and the AFs have been described in the first paper of this series [1]. A major issue in human movement analysis is the identification of ALs and the reconstruction of their position in a selected set of axes, namely the AL calibration [1–3]. ALs can be either internal or subcutaneous and in general the determination of their location lacks accuracy and precision. This affects AF position and orientation precision and, consequently, the estimation and interpretation of joint kinematics and kinetics.

This paper reviews the information available in the literature regarding the precision and accuracy of the determination of the location of both internal and palpable ALs, and thus have the relevant AFs, as well as the sensitivity of joint kinematics variables to AF precision and accuracy. Given the relevance of AF axes determination in allowing the correct interpretation of joint kinematics, definitions of AFs aimed at reducing joint kinematics sensitivity to AL uncertainty are also discussed.

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