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Journal of Biomechanics 36 (2003) 1159–1168

JOURNAL OF BIOMECHANICS

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Repeatability of gait data using a functional hip joint centre and a mean helical knee axis

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Accepted 7 February 2003

Abstract

Repeatability of traditional kinematic and kinetic models is affected by the ability to accurately locate anatomical landmarks (ALs) to define joint centres and anatomical coordinate systems. Numerical methods that define joint centres and axes of rotation independent of ALs may also improve the repeatability of kinematic and kinetic data. The purpose of this paper was to compare the repeatability of gait data obtained from two models, one based on ALs (AL model), and the other incorporating a functional method to define hip joint centres and a mean helical axis to define knee joint flexion/extension axes (FUN model). A foot calibration rig was also developed to define the foot segment independent of ALs. The FUN model produced slightly more repeatable hip and knee joint kinematic and kinetic data than the AL model, with the advantage of not having to accurately locate ALs. Repeatability of the models was similar comparing within-tester sessions to between-tester sessions. The FUN model may also produce more repeatable data than the AL model in subject populations where location of ALs is difficult. The foot calibration rig employed in both the AL and FUN model provided an easy alternative to define the foot segment and obtain repeatable data, without accurately locating ALs on the foot.

Keywords: Kinematics; Kinetics; Repeatability; Gait analysis

1. Introduction

Efforts have been made to reduce errors associated with photogrammetric techniques and skin movement artefacts during motion analysis, to accurately determine the position and orientation of body segments. Skin movement artefact has been shown to be reduced by employing a 'CAST' technique, whereby three or more clusters of markers are placed on each segment to create technical coordinate systems (TCSs) (Cappozzo et al., 1995). Anatomical landmarks (ALs) are then defined relative to the TCSs in a static trial to reconstruct an anatomical coordinate system (ACS) during a dynamic trial (Cappozzo et al., 1995; Lucchetti et al., 1998). However, imprecise location of ALs can lead to mislocation of the ACS and subsequent joint centres, which propagates to errors in joint kinematics and kinetics (Holden and Stanhope, 1998; Della Croce et al., 1999; Stagni et al., 2000). Errors associated with the imprecise location of ALs have been noted as the greatest source of error in motion analysis, compared to instrument error or skin movement artefact (Della Croce et al., 1997). These findings raise concerns regarding the repeatability of models using ALs to define an ACS, which from a clinical perspective, is of paramount importance. Methods to reduce any variability in locating ALs and defining the ACS therefore warrant investigation.

Numerical methods can be used to determine joint centres and axes of rotation relative to marker clusters, without the need to accurately locate ALs. Techniques have been previously established to estimate joint centres for the hip (Cappozzo, 1984; Shea et al., 1997; Leardini et al., 1999), and the shoulder (Stokdijk et al., 2000), by moving the joint through a functional range of motion, assuming a true 'ball-and-socket' articulation. Methods have also been developed to determine 'optimal' axes or mean helical axes of rotation for the knee (Boyd and Ronsky, 1998; Churchill et al., 1998) and elbow (Chéze et al., 1998; Stokdijk et al., 1999)

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0021-9290/03/$ - see front matter
doi:10.1016/S0021-9290(03)00087-3