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Gait and Posture 20 (2004) 213–221
GAIT POSTURE
www.elsevier.com/locate/gaitpost

Repeatability of an optimised lower body model

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Received 23 July 2003; received in revised form 17 September 2003; accepted 20 September 2003

Abstract

The optimisation technique, optimised lower-limb gait analysis (OLGA), is described together with a preliminary study of repeatability compared to an implementation of the Newington–Helen Hayes gait model. The study of repeatability used a single healthy subject, three physiotherapists as observers and provided approximately 100 gait cycles. Improvement in intra- and inter-observer repeatability of the lower limb model was found for OLGA, indicated by significantly lower standard deviations (S.D.s) in local marker co-ordinate (a measure of rigidity of the marker attachment), together with reduced S.D. in the estimated length of the bone segments. The S.D. in the inter-hip distance measured by OLGA ($N = 25$) was found to be only 2.4 mm. The repeatability of clinically significant output variables (joint angles, forces and moments) was also improved, with the inter-observer variations for joint angles and forces being significantly lower for OLGA. Euler angle component cross-talk effects frequently reported at the hip, knee and ankle were also successfully reduced by OLGA, this being the chief cause of the improvement in inter-observer repeatability.

Keywords: Gait analysis; Repeatability; Optimisation; Inverse kinematics; Kalman filter

1. Introduction

Repeatability of motion analysis data, particularly in gait, is coming under increasing scrutiny [1]. The current models used for lower limb analysis fall into three broad categories.

1.1. Landmark specific marker placement

This type of model relies on accurately placed markers that correspond to important bony landmarks and axes, from which the geometry of the bones and joint axes is determined using standardised algorithms based on vector algebra. The most notable example is the Newington Hospital Helen Hayes model [2,3]. Locations of the joint centres and bones over time are then used to calculate joint kinematics and kinetics.

1.2. Marker clusters with technical–anatomical calibration

This includes those models that use less specific placement of marker clusters and a technical–anatomical calibration process to identify manually the required landmarks and axis directions to reconstruct the underlying bone and joint geometry. Such models include the Cleveland Clinic method (Motion Analysis Corp, Santa Rosa, USA) and technical—anatomical calibration techniques [4,5]. The relationships established in the calibration phase are used to find the position and orientation of the lower limb bones and calculate the resulting kinematics and kinetics.

1.3. Estimation of functional joint centres and axes

Many methods have been proposed for locating the joint centres and axes of the lower limbs functionally from marker motion and hence reconstruct the underlying bony anatomy more reliably [6–8]. These optimised joint centres are then used in models similar to those of type (i) and (ii) to deduce joint kinetics and kinematics.

There are two significant problems with the assumptions made in the first two types of model, in that firstly the underlying model geometry is related to the surface landmarks by the same rules for every subject and secondly that the placement of the markers themselves (or location of landmarks in calibration) is a repeatable operation. The repeatability of placing surface markers and the effects that this has on the kinematics and kinetics has also been documented [9,10].

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0966-6362/$ – see front matter © 2003 Published by Elsevier B.V.
doi:10.1016/j.gaitpost.2003.09.004