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Measurement of Lower Extremity Kinematics During Level Walking

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Summary: A simple external marker system and algorithms for computing lower extremity joint angle motion during level walking were developed and implemented on a computer-aided video motion analysis system (VICON). The concept of embedded axes and Euler rotation angles was used to define the three-dimensional joint angle motion based on a set of body surface markers. Gait analysis was peformed on 40 normal young adults three times on three different test days at least 1 week apart using the marker system. Angular motion of the hip, knee, and ankle joints and of the pelvis were obtained throughout a gait cycle utilizing the three-dimensional trajectories of markers. The effect of uncertainties in defining the embedded axis on joint angles was demonstrated using sensitivity analysis. The errors in the estimation of joint angle motion were quantified with respect to the degree of error in the construction of embedded axes. The limitations of the model and the marker system in evaluating pathologic gait are discussed. The relatively small number of body surface markers used in the system render it easy to implement for use in routine clinical gait evaluations. Additionally, data presented in this paper should be a useful reference for describing and comparing pathologic gait patterns. **Key Words:** Gait analysis—Joint angles—Gait parameters—Biomechanical model—Sensitivity analysis.

Quantitative gait analysis is an important clinical tool for quantifying normal and pathological patterns of locomotion, and has been shown to be useful for prescription of treatment as well as in the evaluation of the results of such treatment (1,6,16,17). Typically, data acquired during a clinical gait analysis include relative positions and orientations of body segments, foot–floor reaction forces, temporal–distance parameters, and phasic activity of muscles of the lower extremities. Several practical methods in current use provide relative orientation of segments either directly or as a derived parameter from measurements of relative position of segments. For example, electrogoniometers (5,10–12,24) have been used to record instantaneously the three-dimensional joint rotation of lower extremity. Accelerometers have also been used for indirect measurement of angular displacements of limbs (8,14,20). Interrupted light photography has been used to derive sagittal plane motion patterns (15,18) by monitoring reflective markers placed on key anatomical locations. Cine film photography (15,23) has been utilized to quantify the motion patterns in three dimensions. Modern computer-aided systems such as VICON (4) and SELSPOT (2) provide accurate three-dimensional spatial positions of reflective skin (surface) markers placed on key anatomical sites on the lower extremities. From these positional data, the relative angular rotation of the individual body segments are derived using analytical techniques based on a biomechanical model of the lower extremity.

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on a set of surface markers and the relative rotations between segments were determined using orthopedic Euler angle definitions. The errors introduced by inaccuracies in the definition of the embedded coordinate system (flexion–extension axis) and alignment were quanitified. A group of 40 normal subjects was evaluated and the results were presented as a normative data base that can be used for comparison purposes. It is hoped that the joint angle measurement technique presented in this paper will provide a uniform method for data acquisition so that it will be possible to compare and/or share gait data between clinical centers.

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