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Tibiofemoral and tibiocalcaneal motion during walking: external vs. skeletal markers

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Abstract

The purpose of this study was to determine the errors in knee (tibiofemoral) and ankle joint complex (AJC; tibiocalcaneal) rotations caused by the skin movement artefact. Intracortical bone pins were inserted into the femur, tibia, and calcaneus of five subjects. Marker triads were attached to these pins, and additionally, six skin markers to the thigh, six to the shank, and three to the shoe. For each subject three walking trials were filmed with three synchronized LOCAM cameras (50 Hz). Flexion/extension, ab/adduction, and longitudinal rotation at the tibiofemoral joint as well as plantar-/dorsiflexion, ab/adduction, and in/eversion at the AJC were calculated from both skin and bone markers during the stance phase of walking. The results showed that the errors in knee rotations were mainly caused by the thigh markers. Knee flexion/extension was generally well reflected with the use of skin markers (mean difference: 2.1°). The agreement between skin and bone marker based kinematics for ab/adduction and internal/external knee rotation ranged from good to virtually no agreement, and in some subjects, the errors exceeded the actual motion. The errors in AJC rotations were mainly caused by the markers on the shoe/foot segment. The tibiocalcaneal rotations were generally well reflected with external markers. However, tibiocalcaneal rotations derived from external markers typically exceeded the true bone motions. The results suggest that (a) knee rotations other than flexion/extension may be affected with substantial errors when using external markers, and (b) tibiocalcaneal rotations are generally well reflected with external markers, but amplitudes are overestimated. © 1997 Elsevier Science B.V.

Keywords: Walking; Gait; Tibiofemoral kinematics; Tibiocalcaneal motion; Knee joint; Ankle joint complex; Tibia; Femur; Calcaneus; Bone pin; Skin movement artefact

1. Introduction

In routine kinematic analysis of human gait, skin markers attached to a segment are typically used to represent the movement of the underlying bone, However, larger errors may be introduced as a result of the relative movement between skin and underlying bone. This source of error, typically referred to as the skin movement artefact, is believed to be the most important error in human movement analysis [1].

Different methods have been used to directly measure in vivo skeletal motion. They include stereo radiography [2,3], bone pins [4–9], external fixation devices [1], and a percutaneous skeletal tracker [10]. However, the applicability of such methods is limited, mainly due to the invasiveness of such procedures. Consequently, routine kinematic gait analysis used for clinical assessment has to rely on measurements based on superficial skin markers. Therefore, knowledge about the skin

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