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Influence of soft tissue artifacts on the calculated kinematics and kinetics of total knee replacements during sit-to-stand

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ABSTRACT

The current study aimed to quantify the soft tissue artifacts of selected markers on the thigh and shank, and their effects on the calculated joint center translations, angles and moments of the knee during sit-to-stand. Ten patients with total knee replacements rose from a chair under simultaneous surveillance of a motion capture system, a force-plate and a fluoroscopy system. The "true" poses of the thigh and shank were defined by those of the femoral and tibial components obtained using a three-dimensional fluoroscopy method. The soft tissue artifacts of the skin markers were calculated as their movement relative to the underlying prosthesis components. The joint center translations, angles and moments at the knee were also calculated separately using skin markers and the registered prosthesis poses. Considerable soft tissue artifacts were found, leading to significantly underestimated flexion and internal rotation angles, and extensor moments, but overestimated joint center translations and adduction. The current study provides accurate data of the kinematics and kinetics of total knee replacements during sit-to-stand. The effects of soft tissue artifacts on the calculated joint center translations, angles and moments were also quantified for the first time in the literature. The results may help in developing guidelines for using skin markers and in establishing databases in the biomechanical assessment of sit-to-stand in patients with total knee replacements.

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1. Introduction

Total knee replacement (TKR) has been the main choice of treatment for advanced degenerative osteoarthritis (OA) of the knee over the last few decades. With a good long-term survival rate, improvement of functional recovery has received much attention [1,2]. Therefore, in evaluating TKR designs, it is essential to assess the functional performance of patients during activities of daily living, such as level walking and sit-to-stand (STS). Being a prerequisite to level walking, STS places much greater mechanical demands on the knee joint than level walking, with greater range of motion [3] and moments [4]. Analysis of the STS movement has proven to be a valid tool for assessing the performance of the knee for TKR patients [5], which has been achieved mostly using skin marker-based three-dimensional (3D) motion analysis techniques [6,7]. A major source of errors in human movement analysis [8] is the associated soft tissue artifacts (STA) which are difficult to eliminate non-invasively [9]. Knowledge of the STA and their effects on the calculated kinematics and kinetics of TKR during STS would be helpful for a better interpretation of the results obtained. It may also help with the development of STA error-compensation methods for reducing their effects.

Previous studies have used invasive approaches to quantify the STA during functional activities [8,10,11], but these methods unacceptably limited the movement itself and restricted the soft tissue displacement relative to the underlying bone. Non-invasive methods based on traditional medical imaging techniques [12,13] are limited to two-dimensional (2D) and/or static measurements. Model-based 3D fluoroscopy methods for measuring in vivo 3D kinematics of TKR presented a good opportunity to study the STA non-invasively [14]. Stagni et al. [15] used subjects with TKR to determine the STA of the markers on the lateral aspect of the lower limbs and away from the joints, and their effects on calculated knee angles during functional activities. Unfortunately, the data were limited to those of two subjects, and the effects of the STA on the

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