ELSEVIER

Gait and Posture 11 (2000) 38–45

GAIT & POSTURE

www.elsevier.com/locate/gaitpost

Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study

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Accepted 8 September 1999

Abstract

The overall goal of this work was to determine an optimal surface-tracking marker set for tracking motion of the tibia during natural cadence walking. Eleven different marker sets were evaluated. The marker sets differed in the location they were attached to the shank, the method used to attach the marker sets to the segment and the physical characteristics of the marker sets. Angular position during stance for each marker set was expressed relative to the orientation of the tibia as measured using bone anchored markers. A marker set consisting of four markers attached to a rigid shell positioned over the distal lateral shank and attached to the leg using an underwrap attachment yielded the best estimate of tibial rotation. Rotational deviations of $\pm 2°$ about the medio–lateral and antero–posterior axes, and $\pm 4°$ about the longitudinal axis did occur even when using the optimal set of markers.

Keywords: Surface-tracking marker; Tibia; Distal lateral shank; Tibial rotation

1. Introduction

One goal of gait analysis is to understand how the bones of the lower extremity move during locomotion. High-speed video is commonly used to achieve this end. A major limitation of video based estimates of skeletal motion is that tracking markers attached to the leg from which estimates are made are separated from bone by soft tissue (skin, muscle and fat). Soft tissue moves relative to the bones as the subject walks and consequently so will the tracking markers. Relative motion caused by soft tissue movement can result in kinematic estimates of peak knee abduction/adduction (Abd/Add) and internal/external rotation (IR/ER) that differ from *true* peak values by as much as 50 and 100%, respectively [1]. Holden and co-investigators reported rotational deviations of up to 8° about the long axis of the shank during late stance for subjects walking at self selected speeds [2]. Similar findings have been reported by Cappozzo and colleagues [3]. The magnitude of these deviations is alarming considering the range of longitudinal rotation of the tibia relative to the femur is approximately 10° during natural cadence walking [4].

Several methods have been proposed to reduce the effect of soft tissue movement on kinematic estimates [5–11]. Unfortunately, these methods require specialized hardware and/or software which limits their applicability and consequently their use. Easier to implement strategies, such as using idealized tracking markers might minimize the effect of soft tissue movement and therefore should be investigated.

It is likely the efficacy of tracking markers is related in part, to several factors. These include: the location of the markers on the segment, the physical characteristics (constrained/unconstrained) of the marker set and the method used to attach the marker array to the leg. For the purposes of this study, a marker set (also referred to as marker array) is defined as a collection of markers ($n \geq 3$) attached to an anatomical segment. Cappozzo and co-workers have shown that the location and physical characteristics of a marker set can influence esti-

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0966-6362/00/$ - see front matter
PII: S0966-6362(99)00042-9