KNEE INTERNAL/EXTERNAL ROTATION MEASUREMENTS BY MEANS OF SKIN MARKERS

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INTRODUCTION

In many gait analysis protocols [1-3], the reliability of three-dimensional knee rotations still remains an issue, also because of the lack of non-invasive validation techniques. The aim of this study was to evaluate experimentally in-vivo this error in different protocols and marker sets. Several multi-marker clusters, including standard spherical markers and calibrated landmarks, were analyzed during gait and elementary exercises. The addition of a few markers to the standard sets was hypothesized to enhance skeletal knee rotation tracking.

METHODS

Six male volunteers (means: 33 years, 79 kg, 176 cm, BMI 25.14) were instrumented with a marker set combining 3 standard protocols [1,3]. Four markers (T1-T4) were placed in the mid thigh around the wand marker (Tw), according to [2]. These were tracked (Vicon Motion Systems, UK) in up-right posture, level walking, knee flexion/extension (FE_knee) and hip flexions/extensions combined with ab/adductions with the knee in full extension at different angles in the transversal plane (STAR_hip). In addition to the standard protocol-based analyses, other techniques were utilized for knee rotation calculations, by using the same femur anatomical frame [2] and the same joint convention [5]. In particular, a medial epicondyle (ME) marker was added, and a number of technical frames were calculated by increasing the number of markers in the thigh clusters for SVD-based [4] reconstructions of anatomical landmark trajectories. The hip joint center (HC) was always taken as defined by regression equations [6]. Error is calculated as the difference between expected physiological [7-8] and measured range of motion of the knee internal/external (I/E) rotation.

RESULTS AND DISCUSSION

Maximum errors of knee I/E rotation were 32, 30.8, 53.8 degrees, respectively in walking, FE_knee and STAR_hip. In walking and STAR_hip, the clusters with the medial epicondyle marker showed the largest probability for the error to be below the average (about 70%, in Figure 1). The single best estimation of I/E rotation was obtained by adding the medial epicondyle marker, though this is not viable in all subjects and not true for every motor task. In walking, the error from the cluster with all nine markers is one fifth of that from the worst cluster (Figure 2). The markers placed in the distal thigh reduced the error to about 50% in all tasks. As the analysis of errors shows, there is a significant possibility to reduce maximal errors by increasing the number of markers in the cluster (Figure 2).

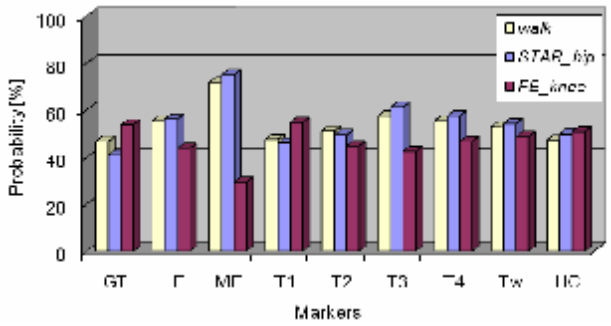

Figure 1: Probability for the error to remain below the mean including each of the available markers.

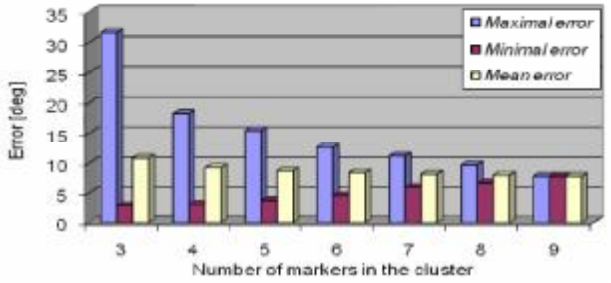

Figure 2: Maximal, minimal and mean error during walking, based on the number of markers in the cluster.

CONCLUSIONS

Skeletal knee rotations can be fully mis-tracked when calculated from standard marker-sets, though obtained also in isolated and very large thigh rotations, not exercised in daily living activities, i.e. FE_knee and STAR_hip. Important reductions of this error can be obtained by including additional markers at the central and distal areas of the thigh. A medial epicondyle marker or a few additional markers on the distal thigh reduce the errors to a large extent.

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