CAN HIP AND KNEE KINEMATICS BE IMPROVED BY ELIMINATING THIGH MARKERS?

1 Brian Schulz and 2 Wendy Kimmel

1 VA HSR&D/RR&D Center of Excellence, Maximizing Rehabilitation Outcomes, James A. Haley Veterans' Medical Center, Tampa, FL, USA
2 Running Injury Clinic, Department of Kinesiology, University of Calgary, Calgary, AB, Canada
email: Brian.Schulz@va.gov

INTRODUCTION

Marker sets developed for gait analysis are often applied to more dynamic tasks with little or no validation, despite known complications of soft tissue artifact. To address this issue, here we present a comparison of the hip and knee kinematics of a single unimpaired male experimenter (height=1.7m, mass=84kg) as calculated by five concurrently-worn marker sets during eight different tasks.

METHODS

The first three tracking marker sets evaluated were Helen Hayes using 1) proximally-affixed thigh wands (HHprox), 2) distally-affixed thigh wands (HHdist), 3) patellar markers instead of thigh wands (HHpat). The remaining two marker sets used rigid four marker clusters on 4) shank & thigh (C-ST), and 5) shank only (C-S). Pelvis and foot segment definitions, joint centers, and segment coordinate systems were shared by all marker sets.

The first three tasks were femoral internal and external rotation tasks with 1) hip neutral and knee at full extension, 2) hip neutral and knee flexed to 90°, and 3) both hip and knee flexed to 90°. The remaining five tasks 4) walking along a straight path (walking), 5) walking in two clockwise or counterclockwise circuits of a 1m radius circle (turning), 6) running along a straight path (running), 7) maximal height jumping (jumping), and 8) maximal length out-and-back lunging (lunging).

RESULTS AND DISCUSSION

The shank-only marker set (C-S) was capable of detecting the most hip external-internal rotation, yet only did so during tasks where greater hip axial motions would be expected (Fig. 1). In general, few and small differences in knee and hip flexion-extension were observed between marker sets, while many and large differences in knee adduction-abduction and external-internal rotations at both the knee and hip were observed. These differences were greatest for more dynamic tasks and greater joint ranges of motion.

The femoral rotation test results were consistent with prior studies [1] and demonstrated that more distal markers were generally capable of capturing greater external-internal hip motions with C-S capturing the most (Fig. 1). This was likely due to substantial proportions of hip external-internal rotations being detected as knee motions by the marker sets using thigh markers (HHprox, HHdist, and C-ST). For example, C-S captured 28-41° (68-242%) more femoral axial rotation than these marker sets, but when the hip external-internal rotation ROM was added to the knee external-internal rotation ROM for task 1 (knee locked) and to the knee adduction-abduction ROM for tasks 2 & 3 (knee flexed to ~90°), the combined ROMs for all five marker sets were within 4.1°, 2.1°, and 2.8° of each other for all three hip rotation tasks. These values were all less than the mean standard deviation for hip external-internal rotation ROM for all marker sets during the three hip rotation tasks (5°). The consistency of this combined knee and hip ROM across marker sets for the hip rotation tasks supports the hypothesis that substantial hip external-internal rotations are being detected at the knee by marker sets using thigh markers.

The femoral rotation tasks demonstrated that C-S was capable of capturing up to 242% more external-internal hip rotation ROM than the other tracking marker sets evaluated, but for the other dynamic...
tasks C-S only detected substantially more for tasks (e.g. turning, jumping, & lunging) that would be expected to elicit greater external-internal rotations. C-S actually captured substantially less external-internal rotation ROM than HHprox and HHdist for running (Fig. 1), where thigh STA during the fast, bouncing gait pattern was likely to have artificially increased the ROM detected by thigh-mounted markers.

At the knee, all but C-S detected motions that were beyond established limits for external-internal rotation (>33º or <-23º) or adduction-abduction (>10º or <-10º) [2]. However, this study reports no ‘gold standard’ to define true skeletal motions. Considering that data from prior studies using intracortical pins have demonstrated substantial inter-subject and inter-study variation [3], no conclusions regarding which marker set most accurately represents true skeletal motions can be drawn from these data.

A consequence of the C-S definition of the thigh and knee segments is that the knee becomes a 2DOF joint. Flexion-extension is always detected, but the other DOF transitions between detecting 100% of knee external-internal rotation (and 0% of adduction-abduction) at 90º of knee flexion to detecting 100% of knee adduction-abduction (and 0% of external-internal rotation at full knee extension. This results in underestimation of knee external-internal rotation as the knee approaches full extension and underestimation of knee adduction-abduction as the knee approaches 90º of flexion (Fig. 5). For external-internal rotation, this property roughly corresponds to the movement permitted by the knee anatomy and to the data from [2]. For adduction-abduction, the underestimation caused by this DOF sharing may be preferable to the substantial hip motions interpreted by marker sets using thigh markers as non-physiologic (ROM>35º) knee adduction-abduction motion.

CONCLUSIONS

Marker set selection is critical to non-sagittal hip and knee motions. The shank-only marker set presented here is a viable alternative that may improve knee and hip kinematics by eliminating errors from thigh soft tissue artifact, particularly for tasks such as turning where hip external-internal rotations are anticipated and/or of interest. Furthermore, it is particularly well-suited to inertial measurement systems, as all lower limbs could be tracked using only five sensors rather than seven. This could substantially reduce the costs of portable gait analysis systems.

REFERENCES


ACKNOWLEDGEMENTS

This study was supported by a VA RR&D Career Development Award (E2964F) and Research Award Enhancement Program.

Figure 1: Mean (SD) hip external-internal rotation ROM for all tasks as calculated by all tracking marker sets.