# MEASUREMENT OF THE SCREW-HOME MOTION OF THE KNEE IS SENSITIVE TO ERRORS IN AXIS ALIGNMENT

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## INTRODUCTION

Several authors have reported on the "screw-home" motion of the knee joint (external rotation of the tibia with respect to the femur during extension) with varying results (Kurosawa et al., 1985; Lafortune et al., 1992). These discrepancies in measurements of axial knee rotation may be due to errors caused by kinematic "crosstalk". Such errors arise when the chosen knee joint coordinate system is not aligned with anatomical axes (e.g., when the flexion-extension axis is not aligned in the mediolateral direction).

The purpose of the present study is to investigate the possibility that screw-home motion of the knee is a manifestation of kinematic crosstalk. It may be that external rotation of the tibia does not *accompany* knee extension but rather *is* knee extension that appears as rotation about a different axis. We hypothesize that small misalignments of the knee joint coordinate system may result in knee extension being misinterpreted as external rotation of a magnitude consistent with reports of measured screw-home motion. Specifically, we will test (1) whether a screw-home motion can be measured where none exists, and (2) whether kinematic crosstalk can hide a screw-home motion that is known to occur. Unlike the sensitivity analyses of Blankevoort et al. (1988) and Kadaba et al. (1990), in which the effects of crosstalk were examined by reinterpreting motion data collected in actual knees, the present study concerns the motion of mechanical linkages with known kinematics.

## METHODS

A Vicon 370 motion analysis system (Oxford Metrics; U.K.) was used to measure the motions of two mechanical linkages (NSH and SH). The linkages had "thigh" and "shank" segments connected either by a simple revolute joint (NSH) or by a geared joint that produced 15° screw-home over 90° knee extension (SH). Local coordinate systems were determined for each segment from the measured locations of anatomical control points (ACPs) using a method similar to that of Cappozzo et al. (1995). The transformation between segment coordinate systems was determined for each linkage as it was manually flexed to 90° and returned to full extension. These transformations were converted into joint angles using the decomposition proposed by Grood and Suntay (1983).

Kinematic crosstalk was apparent in these joint angles and was removed by adjusting the position of one of the ACPs that defined the flexion axis (Woltring, 1994). This first adjustment was made by performing a systematic grid point search for an ACP position that achieved abduction, rotation, and flexion angles that corresponded to the known mechanical behavior of each linkage. The ACP positions were then adjusted a second time to attempt to produce an apparent screw-home rotation in linkage NSH and to remove screw-home from linkage SH.

Measurements of anatomical landmarks on human subjects were made to determine inter-observer variability in knee flexion axis orientation. The femoral epicondyles of a single subject were palpated and identified by five experienced observers, and flexion axes were determined that passed through these points.

## RESULTS

A flexion axis was found for each linkage that resulted in measurement of joint angles that corresponded to its known motion (Figure 1). Further displacement of the flexion axis by 19.5° in linkage NSH resulted in an apparent screw-home pattern (Figure 2, left). Displacing the flexion axis of linkage SH by 8.5° resulted in the screw-home behavior of this linkage being obscured (Figure 2, right). The apical angle of the cone subtended by the flexion axes determined from anatomical landmarks by the five observers was 13.3°.

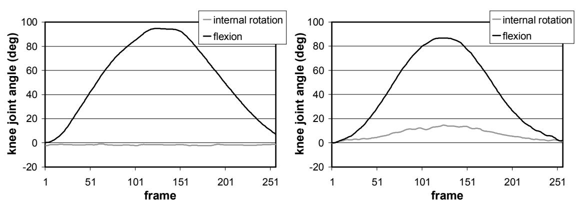


**Figure 1:** Rotation and flexion angles for linkages NSH (left) and SH (right) following removal of kinematic crosstalk effects.

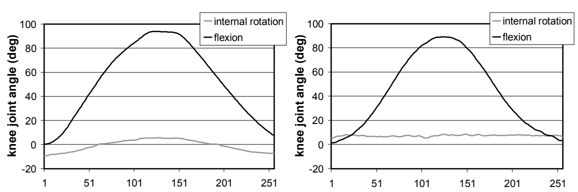


**Figure 2:** Rotation and flexion angles for linkages NSH (left) and SH (right) subject to crosstalk induced by reorienting the flexion axis. Linkage NSH (which featured a simple hinge) seemingly exhibited a screw-home rotation, and the screw-home rotation of linkage SH was made to disappear.

## DISCUSSION

The results of this study demonstrate that kinematic crosstalk resulting from joint axis misalignment can cause screw-home motion to be measured where none exists and can prevent a true screw-home motion from being measured. The angular displacements of the flexion axis necessary to effect these changes were consistent with the inter-observer range of flexion axis orientations found by palpating the femoral epicondyles. Any technique that relies on accurate estimation of joint axes is subject to these crosstalk errors, including video-based motion analysis, roentgen stereophotogrammetry, and electrogoniometry. Small out-of-plane rotations measured along with large flexion angles should be examined carefully by clinicians to ensure that they are not the product of kinematic crosstalk.

The conclusions drawn from this study are based on the motions of mechanical linkages, not human knees. As such, they provide no insight into whether screw-home motion normally occurs in actual knees. Knowledge of the motion of the mechanical linkages did, however, allow crosstalk errors to be separated from the true motion being measured. Mechanical models such as these provide reference motions useful for the study of errors in the measurement of joint rotations.

## REFERENCES

Blankevoort, L. et al. (1988), *J. Biomech.*, **21**, 705-20.
Cappozzo, A. et al. (1995). *Clin. Biomech.*, **10**, 171-8.
Grood, E. S., W. J. Suntay (1983). *J Biomech. Eng.*, **105**, 136-44.
Kadaba, M. P. et al. (1990). *JOR*, **8**, 383-92.
Kurosawa, H. et al. (1985). *J. Biomech.*, **18**, 487-99.
Lafortune, M. A. et al. (1992). *J. Biomech.*, **25**, 347-57.
Woltring, H. J. (1994). *J. Biomech.*, **27**, 1399-414.

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