

ESTIMATION OF KNEE JOINT SURFACE ROLLING/GLIDING KINEMATICS VIA INSTANT CENTER OF ROTATION MEASUREMENT

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INTRODUCTION

One approach to assessing sagittal plane intrinsic knee joint kinematics has been through application of the concept of the path of instant centers of rotation (PICR) (Frankel et. al., 1971; Smidt, 1973). Rolling/gliding kinematics have been inferred from such studies. When a great amount of rolling relative to gliding occurs between joint surfaces, the PICR is located in close approximation to the point of contact. Conversely, when a lesser amount of rolling relative to gliding occurs, the PICR is located further from the point of contact. Such studies, however, have failed to quantify a relationship between PICR and intrinsic joint surface rolling and gliding. Moreover, these studies analyzed only non-weight bearing (NWB) knee extension; it is not known whether PICR and rolling/gliding kinematics are identical for NWB and weight bearing (WB) movement conditions.

The purposes of this study were to (1) describe a 2-dimensional analytic knee model for estimating joint surface rolling and gliding based on PICR measurements, and (2) quantify and compare knee joint surface rolling kinematics in normal subjects for NWB and WB movement conditions.

METHODS

11 adults (6 male, 5 female) without history of right knee injury or surgery participated in this study. Reflective markers were taped 10 cm distal to the greater trochanter, 5 cm

proximal to the lateral femoral epicondyle, at the fibular head and lateral malleolus. NWB and WB knee extension movements were recorded and processed at 60 Hz with Ariel Performance Analysis System software (APAS99, rev. 3.5). A local reference system at the lateral femoral epicondyle was defined. Instant center of rotation (ICR) locations were calculated in a manner similar to methods described elsewhere (Hollman & Deusinger, 1999).

A planar knee model was developed to calculate joint surface contact points and to quantify rolling/gliding kinematics relative to selected ICR locations. The distal end of the femur was configured from previous anatomical research (Nuno-Siebrecht & Ahmed, 1998) to incorporate sagittal plane geometry using two discs, each having a distinct radius of curvature (2 cm posteriorly and 4 cm anteriorly). The proximal tibia was modeled as a flat surface. Femoral contact points were calculated at 10^0 intervals based on the relationship $s = r \theta$, where s represents the arc length between contact points, r represents the radius of curvature, and θ represents a constant angular displacement of 10^0 (0.175 radians). Based on these selected femoral contact point locations and ICR data obtained experimentally, the relative proportion of rolling to gliding was calculated via the *slip ratio* (O'Connor & Zavatsky, 1990), which is defined by the ratio s_m / s_f , where s_m is the displacement (arc length) from an initial contact point to the next contact point on the convex surface and s_f is the displacement

from an initial contact point to the next contact point on a flat surface. For a joint modeled in 2-D as a disc on a flat surface, s_m and s_f are given by

$$s_m = r_m \theta$$

and

$$s_f = (r_m - r_{icr}) \theta$$

where r_m is the radius of the convex surface segment, r_{icr} is the radius from the ICR location to the femoral contact point, and θ is angular displacement of the convex surface, expressed in radians.

A two-factor repeated-measures ANOVA was used to test the null hypothesis that no difference in rolling kinematics existed between movement conditions at any knee angle ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Graphic representation of NWB and WB PICR patterns is presented in the Figure. Repeated measures ANOVA revealed that the movement condition by knee angle interaction was significant ($F = 6.50$, $p < .01$) and subsequent residual interaction effects testing revealed that differences in joint surface rolling occurred between movement conditions in the terminal 20° of knee extension. The table presents % rolling results obtained through terminal extension.

Results suggest knee joint rolling/gliding kinematics may differ between movement conditions. A greater proportion of joint surface rolling occurred in the terminal 20° of WB knee extension than NWB knee extension.

Figure. NWB and WB PICR patterns.

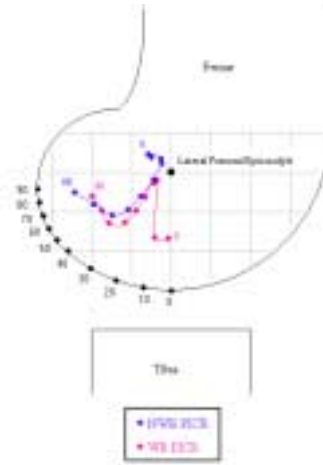


Table. % Rolling values obtained for each movement condition.

KneeAngle	% Rolling	
	NWB	WB
30	56.2	59.5
20	55.0	58.6
10	53.6	70.8
0	53.5	68.9

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