Analysis of Frontal Plane Video to Determine Sagittal Plane Knee Kinematics

Cincinnati Children's® Sports Medicine Biodynamics Center

University of Cincinnati

Wordeman, Samuel C.[1,2]; Ford, Kevin R[2,3]; Hewett, Timothy E.[1,2,3,4]; Myer, Gregory D.[2,3,4]

[1]University of Cincinnati, Department of Biomedical Engineering; [2]Cincinnati Children's Hospital, Sports Medicine Biodynamics Center & Human Performance Laboratory; [3]Department of Pediatrics, College of Medicine, University of Cincinnati [4]The Ohio State University Sports Medicine, The Ohio State University

PURPOSE

To develop and validate a simple method to determine sagittal plane knee kinematics from frontal plane video during a box drop vertical jump.

INTRODUCTION

- Knee abduction moment is a known risk factor for anterior cruciate ligament (ACL) injury
- The box drop vertical jump (DVJ) is a commonly employed activity to assess the magnitude of knee abduction moment
- Current screening tools rely heavily on costly or impractical means of capturing video or kinematic and kinetic data from multiple angles
- Determining risk for increased knee abduction moment can be done using basic anthropometrics and frontal and sagittal knee kinematics during DVJ

METHODS

- Twenty (20) female high school athletes performed five (5) DVJ trials from a 31 cm high box
- Motion analysis data collected from a ten (10) camera motion capture system (Eagle Cameras, Motion Analysis Corp, Santa Rosa, CA)
- Frontal and sagittal plane video collected using camcorders
- Frontal plane video frames at initial contact and peak knee flexion were analyzed and hip, knee and ankle joint centers were digitized
- Vector analysis was used to derive third dimensional kinematics from frontal plane coordinates in the following manner:

The depth component (y-axis) of each segment was estimated as shown in Equation 1

$$L_{SY} \cong \sqrt{L_S^2 - L_{SX}^2 - L_{SZ}^2} \qquad \textbf{Eq 1}$$

Where L_S refers to the known length of the tibial or femoral segment and the X and Z components are visible from the frontal plane.

To determine knee flexion angle, the YZ plane projection vectors for each segment were expressed from knee to hip or knee to ankle as shown in Equation 2.

$$\vec{S}_{ZY} = L_{SZ}\vec{e}_Z + \sqrt{L_S^2 - L_{SX}^2 - L_{SZ}^2}\,\vec{e}_Y \qquad \textbf{Eq 2}$$

Where $\vec{e}_\alpha$ represents the unit vector in the Cartesian coordinate system in the direction of alpha.

Using the dot product between the sagittal plane projection vectors gives Equation 3.

$$\Theta_{SP} = \cos^{-1}\left(\frac{\sqrt{L_F^2 - L_{Fx}^2 - L_{Fz}^2} * \sqrt{L_T^2 - L_{Tx}^2 - L_{Tz}^2} + L_{Fz}L_{Tz}}{\sqrt{L_F^2 - L_{Fx}^2}\,\sqrt{L_T^2 - L_{Tx}^2}}\right) \qquad \textbf{Eq 3}$$

- Knee flexion angle (KFA) was defined as the supplemental angle to Θ_{SP}, and was made negative by convention
- KFA calculated using joint center pixel coordinates from frontal plane video at initial contact and peak flexion
- Frontal plane joint center coordinates from 3D motion analysis used to calculate continuous KFA across contact phase
- Correlation between actual and calculated ROM from video
- Paired, two-tailed t tests at 10% intervals from calculated vs actual (3D) knee flexion angle

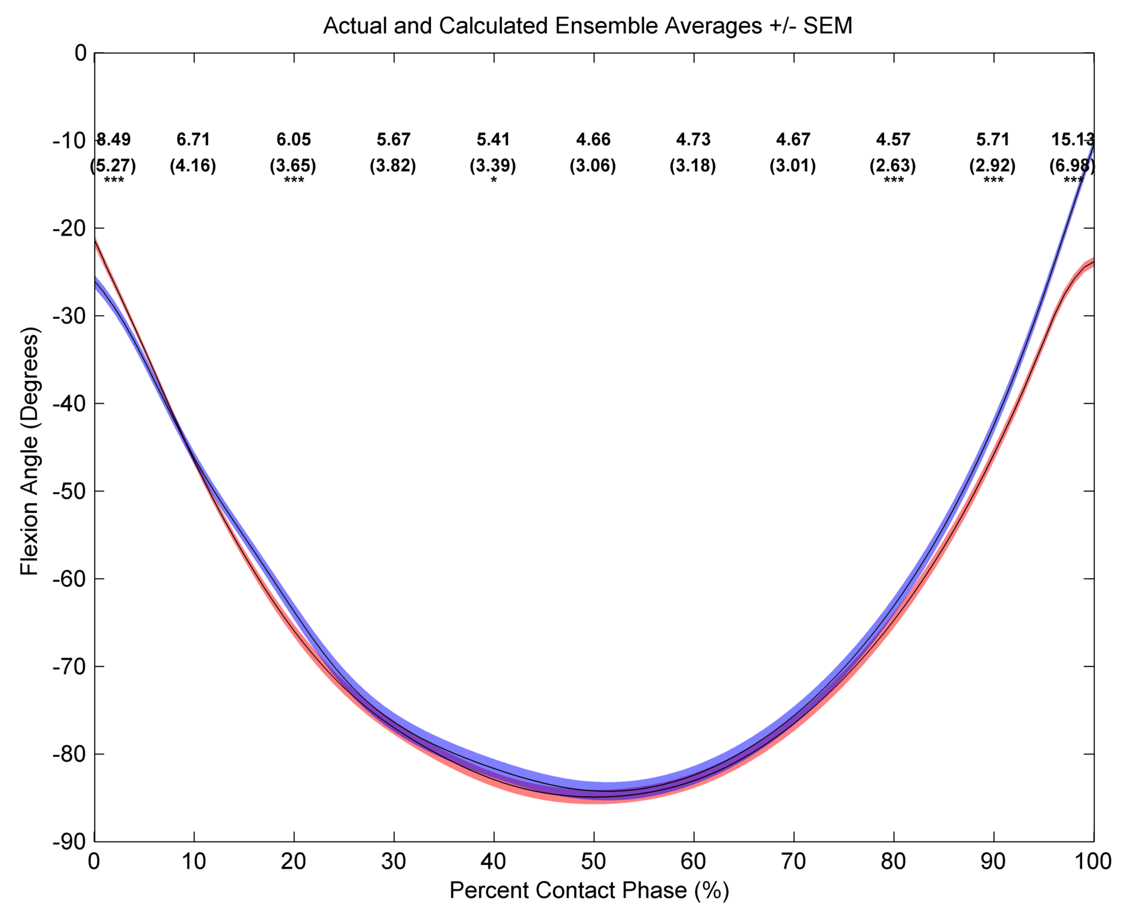

Figure 1: Knee flexion vs Normalized Time from 3D analysis (blue) and calculated from x and z (frontal plane) joint coordinates only. Average RMS Error (SD) are indicated at 10% intervals. *p<0.05, ***p<0.001 from 2-tailed paired t-tests comparing actual and calculated.

RESULTS

- **Figure 1** shows actual (blue) and calculated (red) continuous knee flexion during the contact phase of a DVJ
- Significant differences between the two were noted at low flexion angles, but not at high flexion
- Calculations from frontal plane video accounted for approximately 90% of the actual sagittal plane ROM, as shown in **Figure 2**

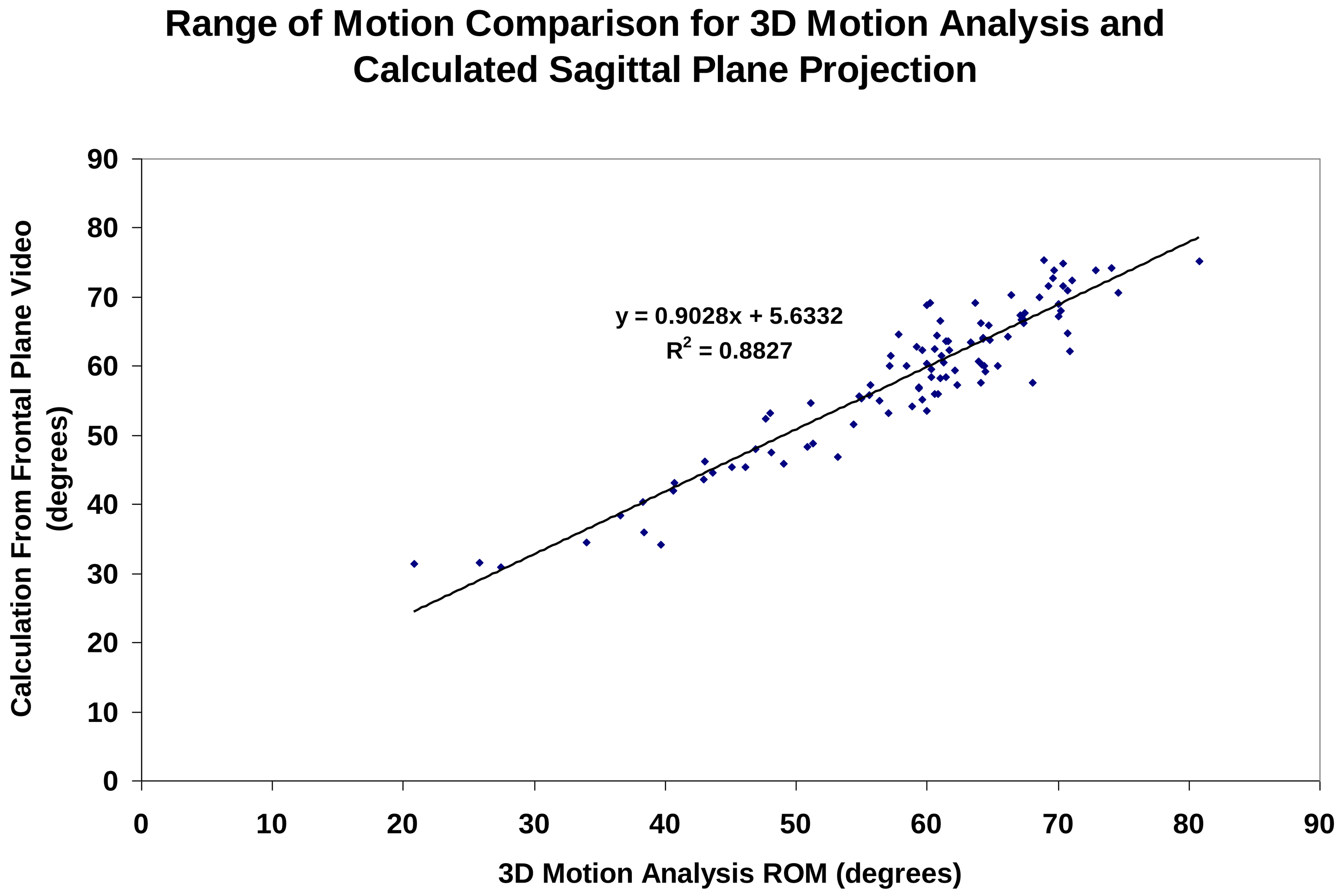

Figure 2: Correlation between knee range of motion (ROM) calculated by frontal plane joint coordinates (y) and observed ROM (x) using the 3D motion analysis system.

DISCUSSION

- Method accounts for most of sagittal plane knee ROM, however lacks ability to take transverse plane motions into account
- Use of this method is currently specific to DVJ and should not be interpreted as universally applicable

CONCLUSIONS

- Further validation is required, however for this specific screening test, the methodology appears to be accurate
- The extent to which the error affects a screener's ability to determine risk of high knee abduction moment is not yet clear