

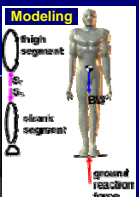
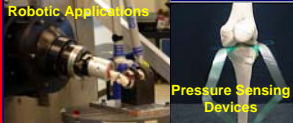
Estimation of In-Vivo Forces During Gait in an Ovine Stifle Joint Requires Motion Reproduction to an Accuracy of Less Than 0.5 mm



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Background

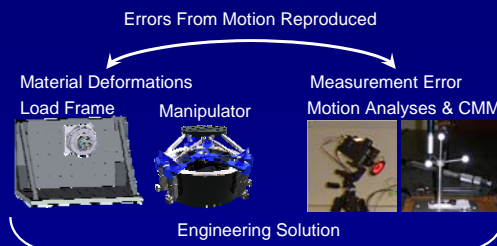
The Challenge - Making accurate, non-invasive, estimations of *in-vivo* forces in the tissues of the knee joint



Small joint displacements have large effects on ligament and joint loads ^{1,2}

This Study - Force differences between multiple *in-vivo* gait cycles, perturbed by 0.5 mm in the medial-lateral (ML), anterior-posterior (AP) and proximal-distal (PD) directions, test the sensitivity of motion errors on *in-vivo* joint, meniscal and anterior cruciate ligament loads

Discussion



- I. Improve Design (Rigidity) & Measurement Accuracy
- &/or
- II. Feedback Control ⁵

Simulated motion errors in gait cycle of 0.5 mm caused over and underestimation of force in joint & ligamentous tissue from 8 to 132 % of the normal value in the ovine stifle joint

Motion errors cause tissue & joint force errors!

Highest difference in joint force from motion error (0.5 mm) was in PD, followed by AP & ML.

Tissue and joint force error depends on :

- I. Joint position,
- II. Force magnitude
- III. System/tissue factors (load cell & manipulator resolution & viscoelastic tissue response - 10 to 40 N)

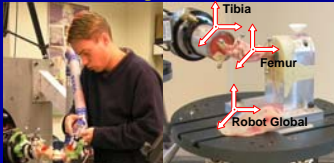
Methods

In-Vivo Kinematics

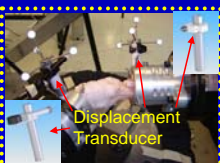


Motion Analysis (accuracy 0.4 ± 0.4 mm ³), n = 2 Adult Suffolk-Cross Sheep

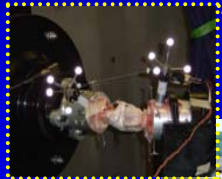
Anatomical Coordinate Systems & Joint Registration



Motion Validation



Motion Reproduction



- 7 Paths
- I. Gait Unchanged
 - II. 0.5 mm Medial
 - III. 0.5 mm Lateral
 - IV. 0.5 mm Anterior
 - V. 0.5 mm Posterior
 - VI. 0.5 mm Proximal
 - VII. 0.5 mm Distal

Mean error 0.07 to 0.83 mm & 0.07° to 0.74° ⁴

Conclusions

- The effect of motion reproduction errors on tissue and joint forces is variable, depending on:
 - I. Direction
 - II. Position of the joint
 - III. Structural properties of the joint
- Estimation of *in-vivo* forces during gait in an ovine stifle joint requires motion reproduction to an accuracy of less than 0.5 mm

Results

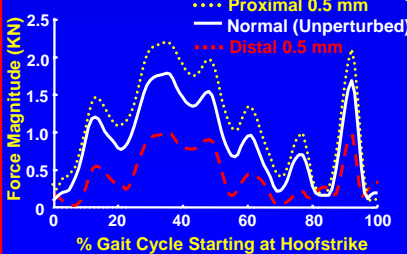


Figure 1. Typical data representing magnitude of joint force from repeating the unperturbed gait path, a path perturbed by (0.5 mm) in the proximal and distal directions

Table 1. Difference in joint force magnitude between unperturbed and paths perturbed 0.5 mm in three degrees of freedom, animal #1 (a = 1), animal #2 (a = 2) & Average (Avg)

Proximal (N)	Distal (N)	Anterior (N)	Posterior (N)	Medial (N)	Lateral (N)	
299 ± 101	488 ± 158	51 ± 18	193 ± 67	118 ± 44	143 ± 38	a = 1
234 ± 50	202 ± 90	59 ± 25	97 ± 37	54 ± 29	79 ± 42	a = 2
267 ± 75	345 ± 124	55 ± 21	145 ± 52	86 ± 36	111 ± 40	Avg

- **Meniscal force** forces differed by 112% and 63%, perturbations in the proximal and distal directions
- **Anterior cruciate ligament** forces differed by 94% and 111% in the anterior and posterior directions

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