ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

NorthShore University HealthSystem

Strain Mapping in Porcine ACLs: Digital Image Correlation During Cyclic Loading and Failure Testing

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Faculty Disclosure Information

- Nothing to disclose

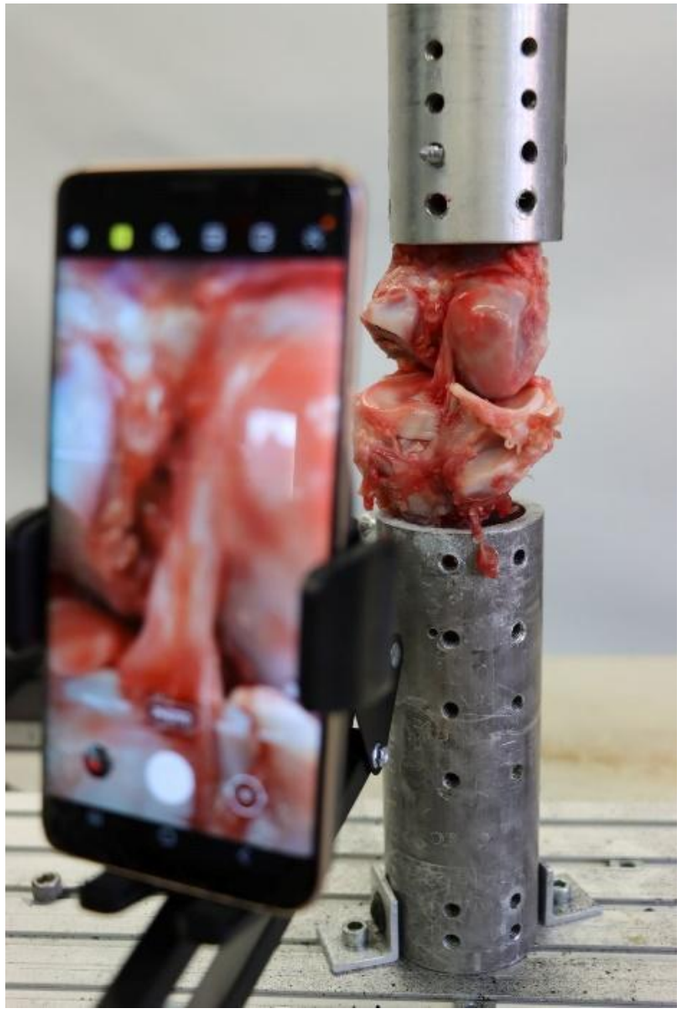
Introduction

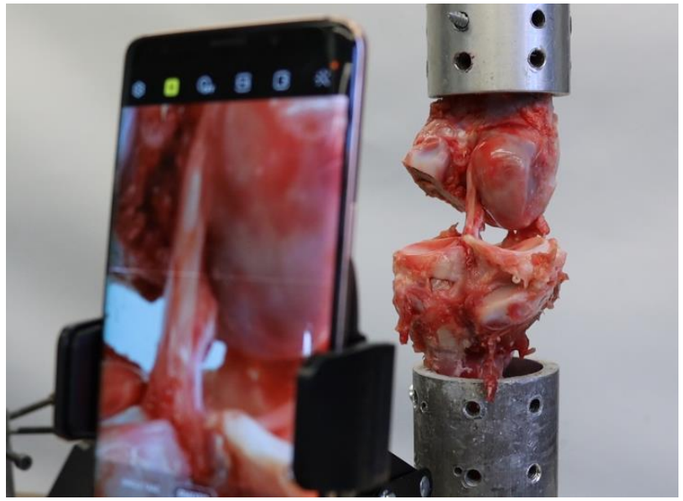
- In the United States over 5 million sports related injuries are reported every year, with approximately 200,000 being adolescent ACL injuries
- ACL tears are a common injury sustained during high-load cutting and pivoting leg movements during sports
- The mechanical loading history of the tissue contributes to damage buildup, increasing the chance of tearing the tissue
- Study Objective: Compare tensile load-to-failure outcomes of porcine ACL samples with varying fatigue using digital image correlation to provide a non-invasive diagnostic of tissue behavior

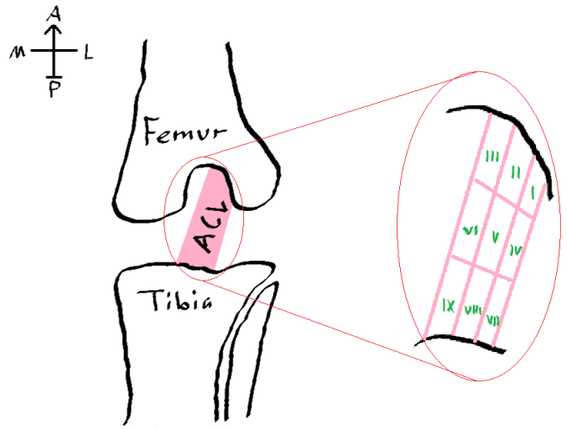
Methods

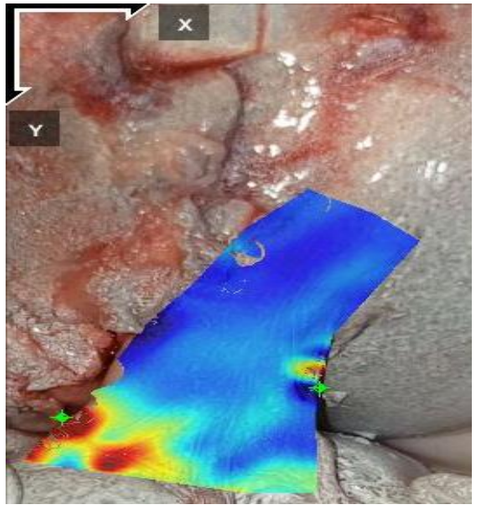
- **Porcine Specimens**
  - 24 fresh-frozen porcine hind-quarters
  - Knee isolated, all ligature except ACL removed
- **Sample Mounting**
  - Femur mounted to machine actuator
  - Tibia mounted to machine base
- **Camera Setup**
  - 5” distance, parallel to surface of ACL
  - 60fps recording, flash on, 3x zoom
- **Testing Procedure**
  - ACL surface covered in high-contrast speckle pattern
  - 8 samples per: uncycled, 100 cycles to 300 N, 100 cycles to 600 N
  - Samples then loaded-to-failure, surface strain correlated to tension

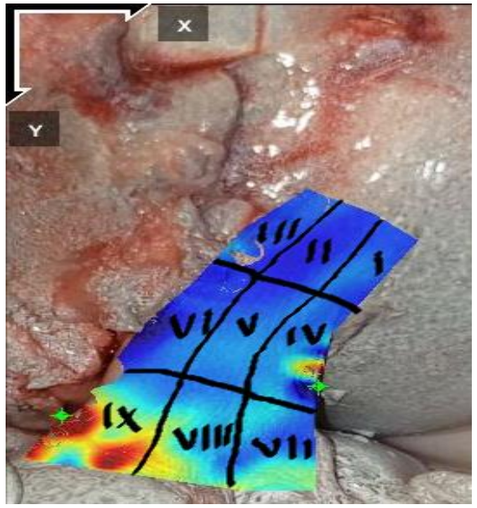
Experimental Setup





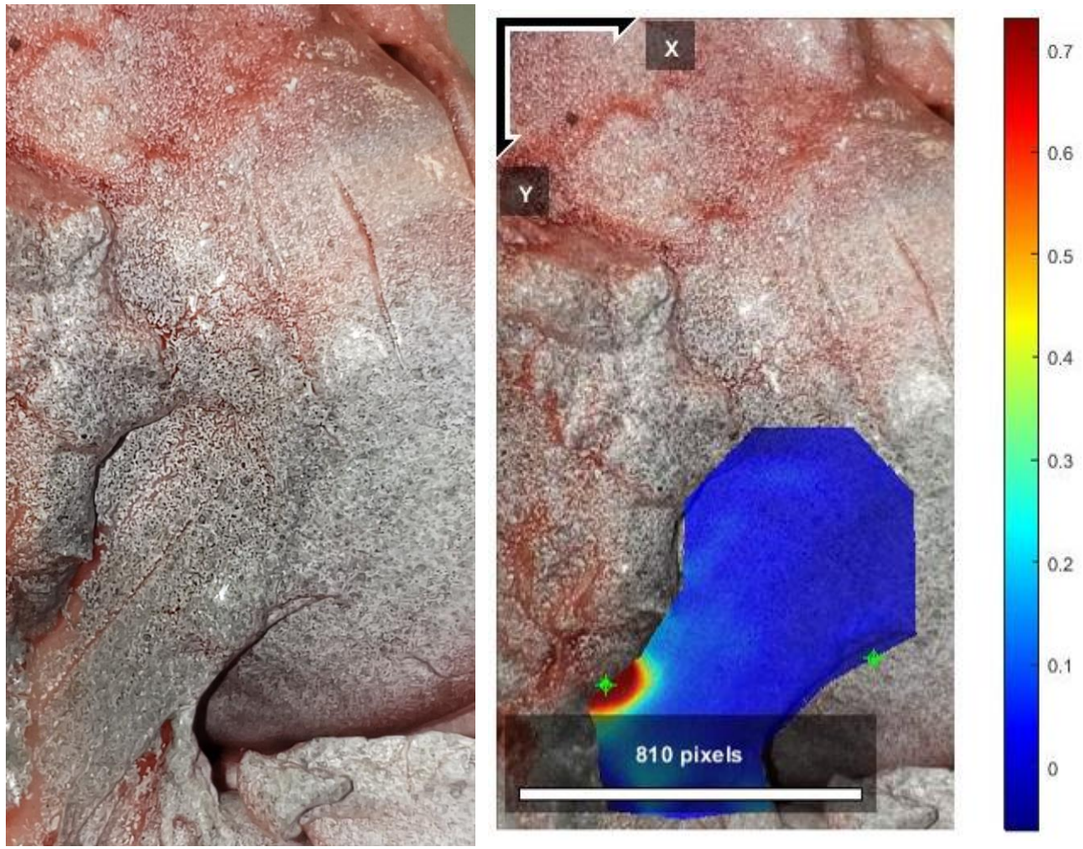






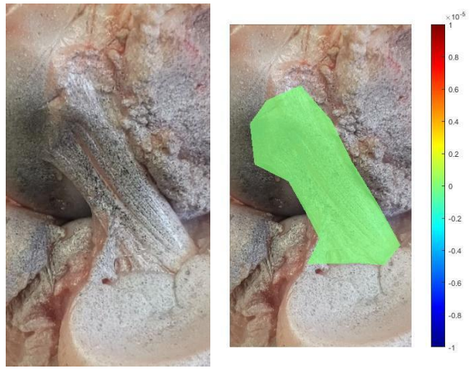
Data Processing

- **Ncorr DIC package in Matlab**
  - Individual frames from recorded videos of each tests
  - Track deformation of surface-bound speckle pattern, convert into strain %
- **MTS Extensometer Load Cell**
  - Time-match video with force and displacement data
  - Correlate strain % and local surface gradient against cyclic fatigue loading type and load-to-failure tension

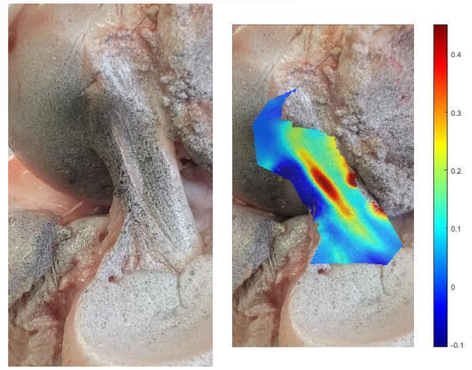


Results

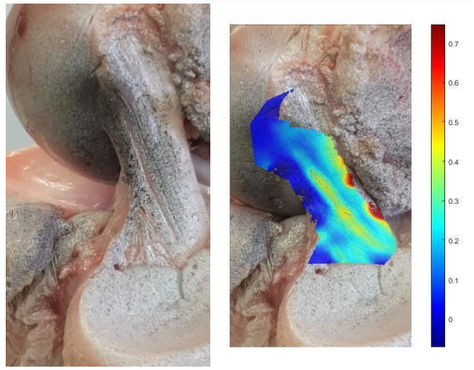
- **Changes in surface strain are tracked throughout the load-to-failure test**
  - Mediolateral bundle
  - Posterolateral bundle
- **Snapshots taken in 200 N increments from 0 N to 1200 N**
  - 1200 N ~ ultimate tensile load
- **Peak strain locations binned into 9 regions for statistical comparison**
  - Low load behavior
  - Peak location migration



0 N



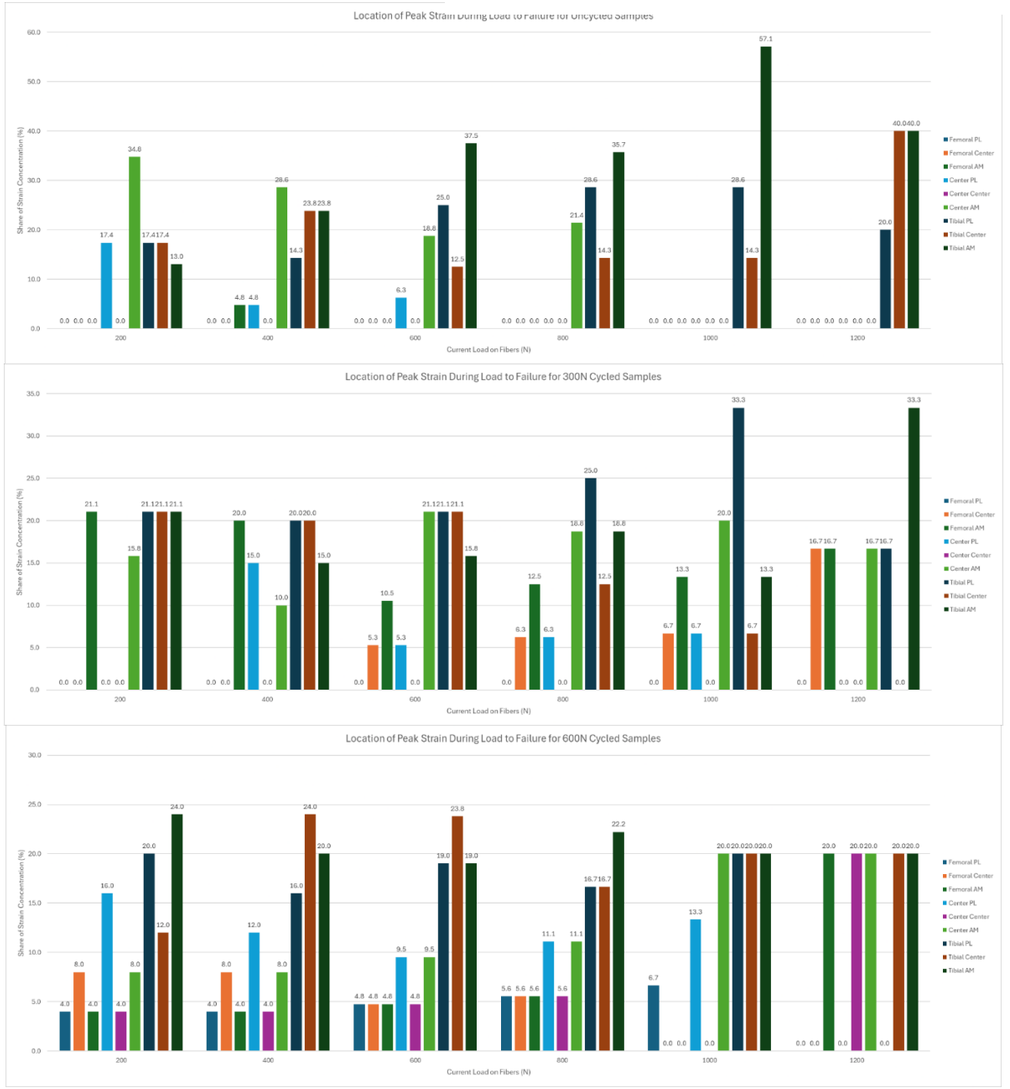
600 N



1200 N

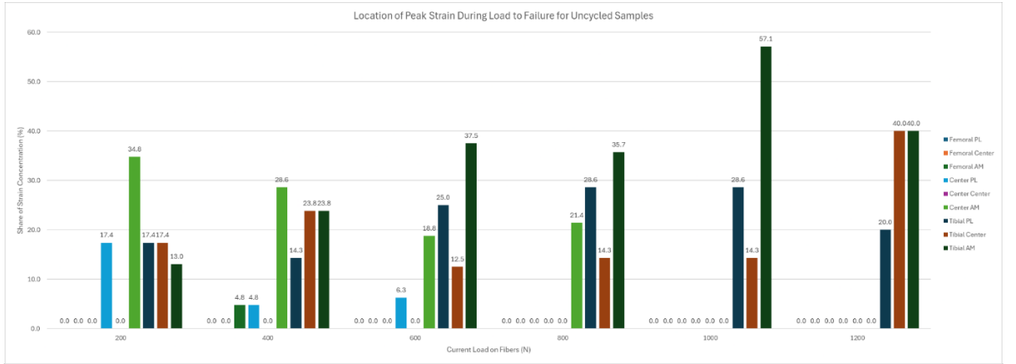
Results

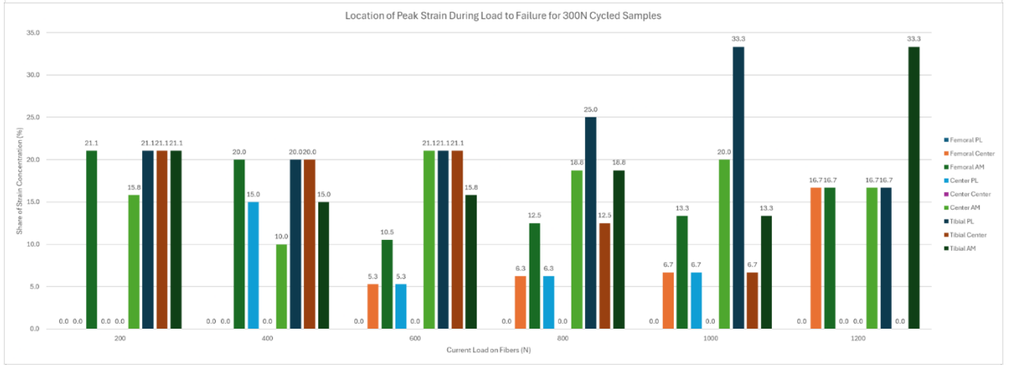
- **Peak strain location varies between the 3 sample sets**
  - Significantly more concentrated distribution at low tensile load in uncycled samples
  - No significance between 300 N and 600 N pre-cycled samples
- **No major significance between load-to-failure behaviors**
  - Wide failure distribution between 800 and 1200 N
  - Most likely tibial detachment, low incidence of femoral detachment

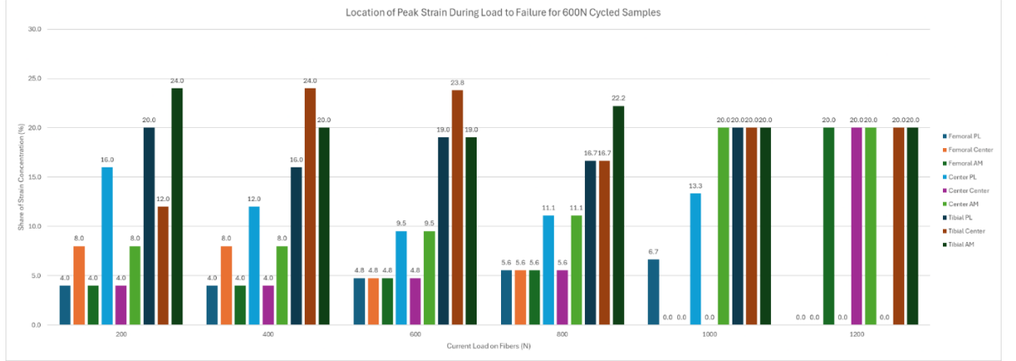


Discussion

- Initial cycling loads (300, 600 N) appear too high to present with differences in tissue damage
- Additional testing is needed at lower # of cycles and lower target tension loads
- Additional work may lead to better understanding of tissue behavior along a Pareto front of cyclic and acute loading







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Conclusions

- Distinct strain patterns between sample groups show peak strain distribution matched well with clinically accepted likely ACL tear location
- Digital image correlation offers a low-cost and customizable approach to non-invasive strain measurements of complex biological tissues undergoing intense loading
- More investigation is needed to determine the precise failure load pattern for different bundles and interfaces within the ACL
- This research contributes to our understanding of biological tissues under dynamic loading conditions

Acknowledgements

- **Northshore Health System, Skokie IL, USA**
  - Research Support

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