ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Size Considerations In The Harvesting Of Quadriceps Tendon Grafts – A Cadaveric Study

Anja M. Wackerle, William G. Gamble, Armin Runer, Svenja A. Höger, Camila Grandberg, Michael P. Smolinski, Mark C. Miller, Patrick J. Smolinski, Volker Musahl

UPMC LIFE CHANGING MEDICINE

Department of Orthopaedic Surgery

PITT SWANSON ENGINEERING MECHANICAL & MATERIALS SCIENCE

University of Pittsburgh

Disclosures

- There are no conflicts of interest to disclose.

Background and Purpose

- Quadriceps tendon (QT) autograft is gaining popularity as ACL graft[1,2]
- QT size varies and can be measured by magnetic resonance imaging/ultrasound[3,4]
- Harvesting of a QT autograft leads to a reduction in tendon size (area)
- Quadriceps muscle weakness has implications for clinical outcomes[5]

Purpose:

Investigate the effect of graft harvest on structural/mechanical properties of the QT.

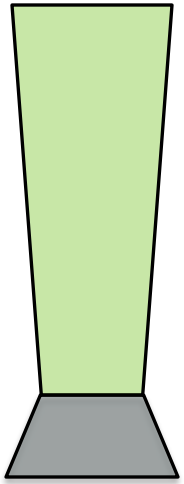
Methods – Specimens

- 10 pairs of extensor mechanisms from fresh frozen cadavers
  - age 49.1 ± 14.7 years (9 male)
  - stored at –20°C and thawed for 24 hours at room temperature

- Each pair randomized into one of two groups:
  - Intact QT group
  - Donor QT group

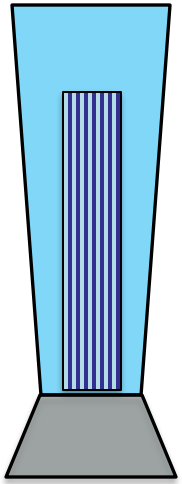
Methods – 3 tissues tested from each knee pair

Knee 1

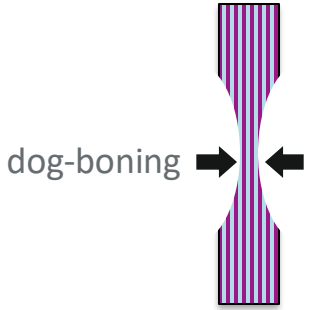


1. Intact QT

Knee 2



2. Donor QT



3. QT graft

Methods – Tissue preparation

- Graft harvest from donor QT:
  - Central partial thickness graft
  - Graft size: 5 mm x 10 mm x 70 mm
  - ➢ graft represented a different % of each donor QT's area
- Laser scanner measured cross-sectional area (CSA) at mid-substance

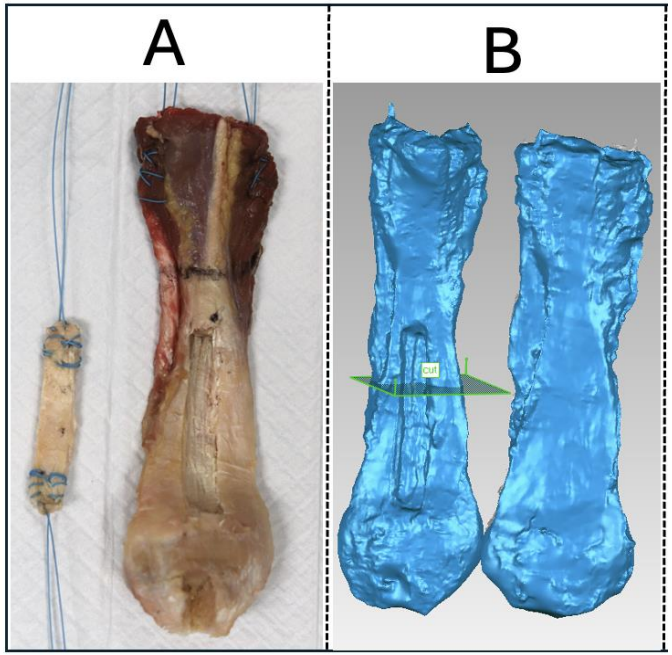


Figure 1: (A) Donor QT with graft, (B) Laser scanner model with CSA measurement

Methods – Tensile testing

- QTs: patella potted in resin blocks; proximal freeze clamp
- graft: proximal & distal freeze clamps
- Loading:
    - cycled 20 times (20-50 N)
    - preloaded with 10 N
    - loaded to failure in axial testing machine (10 mm/min)
- elongation measured with optical markers, using a digital image correlation system (Correlated Solutions, Inc.)

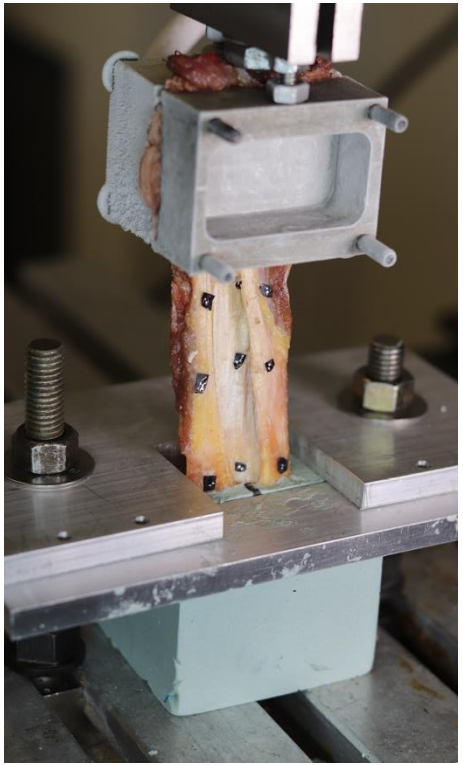


Figure 2: Donor tendon in testing machine.

Results

- Ultimate load & ultimate stress in donor QT ↓
- Elongation/Load in donor QT ↑
- No difference in ultimate strain (note: occur at different loads)
- No difference in elastic modulus

Table 1: Properties of intact and donor tendons (mean±SD)

Property	Intact QT (n = 10)	Donor QT (n=10)	P value
Cross-sectional area, mm^2	213±49	151±33	<0.01*
Ultimate Load, N	5210±999	2553±701	<0.01*
Ultimate Stress, MPa	25.9±8.7	17.1±4.6	<0.01*
Elongation/Load, %/N	0.004±0.002	0.006±0.003	<0.01*
Ultimate Strain	0.21±0.15	0.15±0.05	0.15
Elastic Modulus, MPa	182.3±78.0	163.4±53.7	0.40

Results

- CSA of tendon pairs similar (p = 0.35)
- Graft harvest reduced QTs' CSA by **32%**
- Ultimate load of donor QTs was **50%** lower
- Donor QTs elongated **36%** more per N

→ For each **1%** reduction of a donor QT's CSA due to graft harvest

→ ultimate load reduced by **1.6%**
→ ultimate stress reduced by **1.1%**
→ elongation/load increased by **1.1%**

Discussion and Limitations

- Properties of QT and QT grafts align with previous data[6,7]

- Increased elongation in donor QT could require greater muscle contraction to apply a given load to the tendon
    - ➢ may contribute to prolonged quadriceps weakness after ACLR

- Limitations:
    - assumption of paired tendons having similar biomechanical properties
    - measured properties apply to time zero only

Conclusion

→ The ultimate load and ultimate stress of donor QTs were significantly reduced when compared to the intact contralateral QT

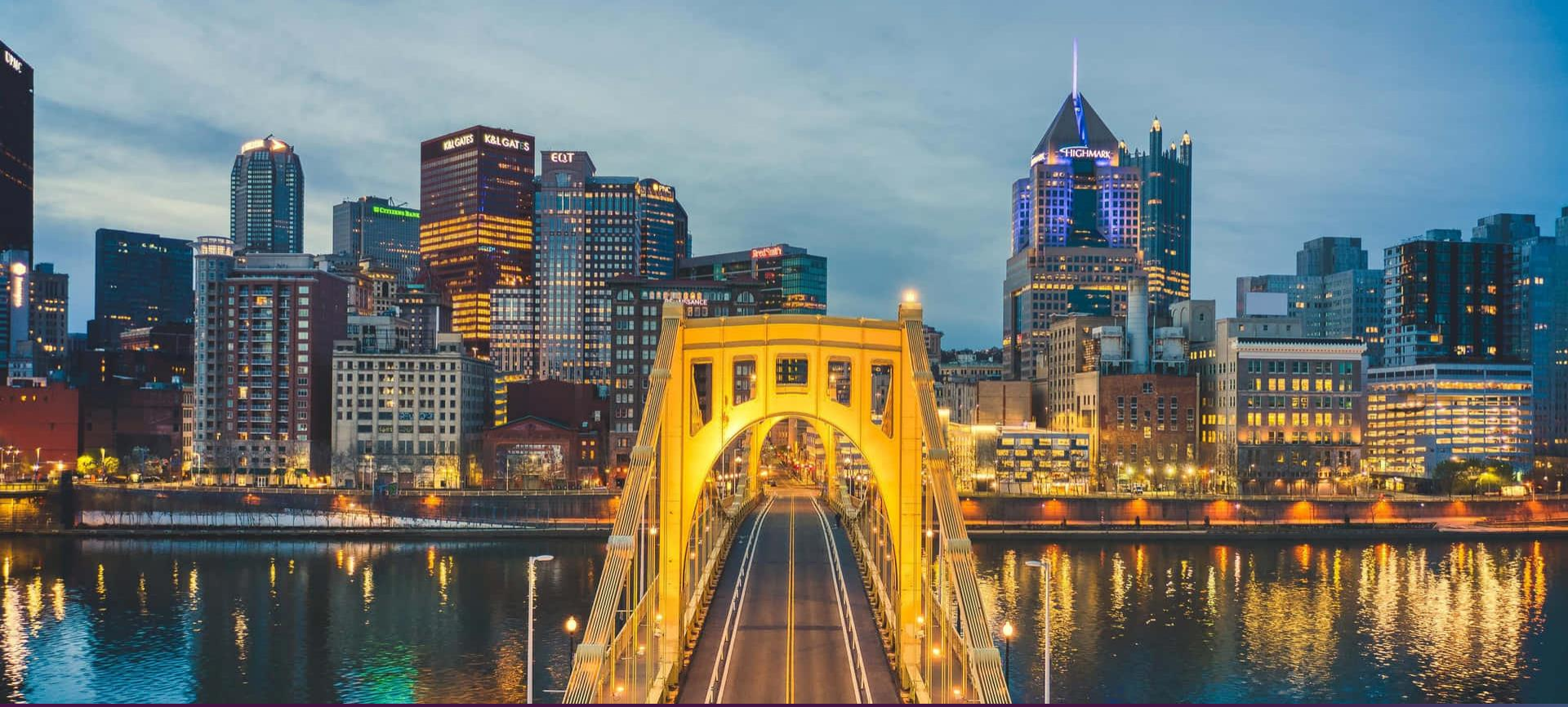
→ Typical **32%** reduction of a donor QT's CSA due to graft harvest resulted in

- an ultimate load decrease of **53%**
- an elongation per unit force (N) increase of **29%**

→ Tendon elongation can be expected to increase approximately the same % as the CSA is reduced by graft harvest

References

1. Sheean, Andrew J., et al. "Quadriceps tendon autograft for arthroscopic knee ligament reconstruction: use it now, use it often." *British Journal of Sports Medicine* 52.11 (2018): 698-701.
2. Geib, Timothy M., et al. "Anterior cruciate ligament reconstruction using quadriceps tendon autograft: intermediate-term outcome." *Arthroscopy: the journal of arthroscopic & related surgery* 25.12 (2009): 1408-1414.
3. Offerhaus, Christoph, et al. "Individualized anterior cruciate ligament graft matching: in vivo comparison of cross-sectional areas of hamstring, patellar, and quadriceps tendon grafts and ACL insertion area." *The American journal of sports medicine*46.11 (2018): 2646-2652.
4. Noorkoiv, M., K. Nosaka, and A. J. Blazevich. "Assessment of quadriceps muscle cross-sectional area by ultrasound extended-field-of-view imaging." *European journal of applied physiology*109 (2010): 631-639.
5. Lepley, Lindsey K. "Deficits in quadriceps strength and patient-oriented outcomes at return to activity after ACL reconstruction: a review of the current literature." *Sports health* 7.3 (2015): 231-238.
6. Adams, Douglas J., Augustus D. Mazzocca, and John P. Fulkerson. "Residual strength of the quadriceps versus patellar tendon after harvesting a central free tendon graft." *Arthroscopy: The Journal of Arthroscopic & Related Surgery* 22.1 (2006): 76-79.
7. Ashton, Dylan M., et al. "The biomechanical, biochemical, and morphological properties of 19 human cadaveric lower limb tendons and ligaments: an open-access data set." *The American Journal of Sports Medicine* 52.9 (2024): 2391-2401.



Thank you!

UPMC LIFE CHANGING MEDICINE

Department of Orthopaedic Surgery

PITT | SWANSON ENGINEERING
MECHANICAL & MATERIALS SCIENCE

University of Pittsburgh