Tibiofemoral Cartilage T1ρ Relaxation Times and Limb Loading 1 Month Post-ACL Reconstruction

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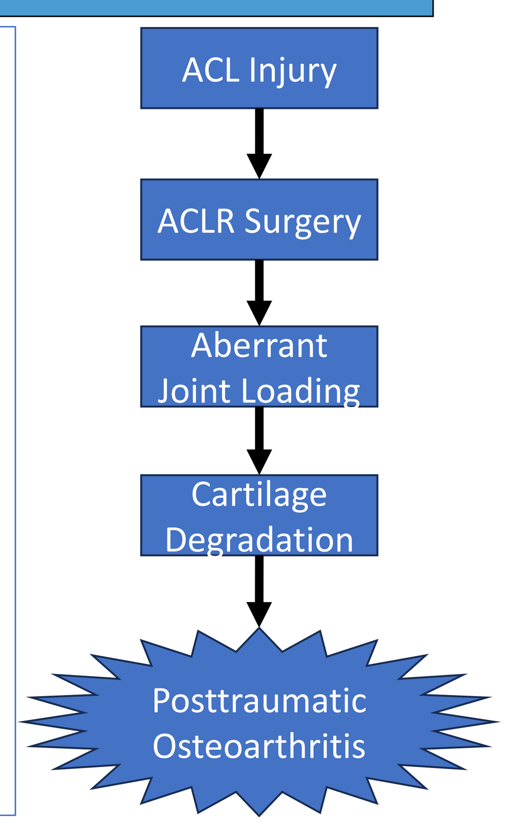
Abstract

Knee osteoarthritis (OA) is widely observed among people who have undergone anterior cruciate ligament reconstruction (ACLR) and manifests quickly[1]. Therefore, to aid in reducing OA risk, it is important to determine what contributes to cartilage degradation. T1ρ relaxation times are successful at detecting changes in cartilage composition, with longer T1ρ relaxation times indicating decreased proteoglycan content, which precedes structural changes, such as joint space narrowing, that are hallmarks of OA[2]. While lesser loading rates determined using vertical ground reaction force (vGRF) are associated with longer T1ρ relaxation times at 6 months post-ACLR[3], it is unclear whether this association is consistent at earlier times points. The purpose of this study was to determine the associations between tibiofemoral T1ρ relaxation times and vGRF and loading rates in the ACLR limb at 1 month post-ACLR. It was hypothesized that smaller vGRF magnitude and lower loading rates would be associated with longer T1ρ relaxation times 1 month post-ACLR. While associations between lesser vGRF instantaneous loading rates and longer T1ρ relaxation times supported the hypothesis, associations between lesser vGRF linear loading rates and shorter T1ρ relaxation times were opposite of the hypothesis. The results show that vGRF instantaneous and linear loading rates influence femoral and tibial cartilage content and degradation differently in the ACLR limb.

Introduction

- ACLR leads to high risk of developing OA[3]
- OA is largely due to cartilage degradation, an irreversible process[2]
- Proteoglycan: component of cartilage that allows it to withstand compressional forces and maintain hydrostatic pressure
- OA cartilage has a low proteoglycan content[4]
- Quantitative magnetic resonance imaging (MRI) techniques are successful at detecting changes in cartilage composition using T1ρ relaxation times[4]
- Greater T1ρ relaxation times = decreased proteoglycan and increased water content[4]
- Joint underloading and overloading during walking have been suggested as contributing factors of knee osteoarthritis



Methods

MRI Analysis

- MRI images of the injured knees were collected using a Siemens Trio 3T scanner
- MATLAB and Slicer were used to pre-process and register the injured limb to the uninjured limb
- Cartilage was manually segmented into regions using ITK-SNAP software (Figure 2)
- T1ρ relaxation times were calculated as an average value of each region

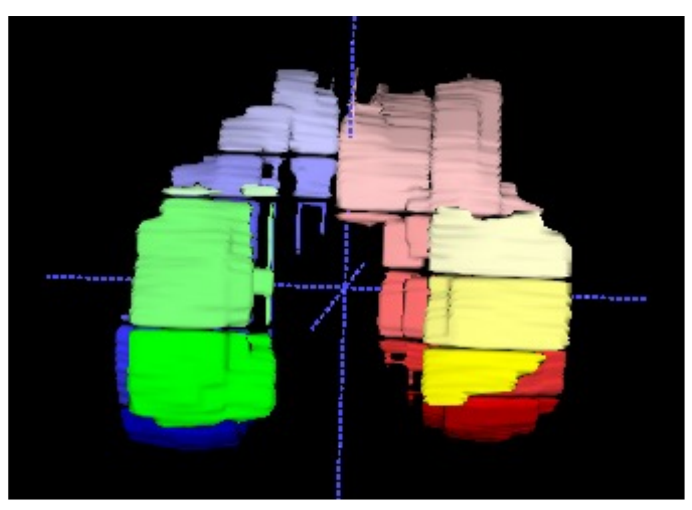


Figure 1. Completed segmentation of the femur and tibia with colors designating sections in 3D perspective.

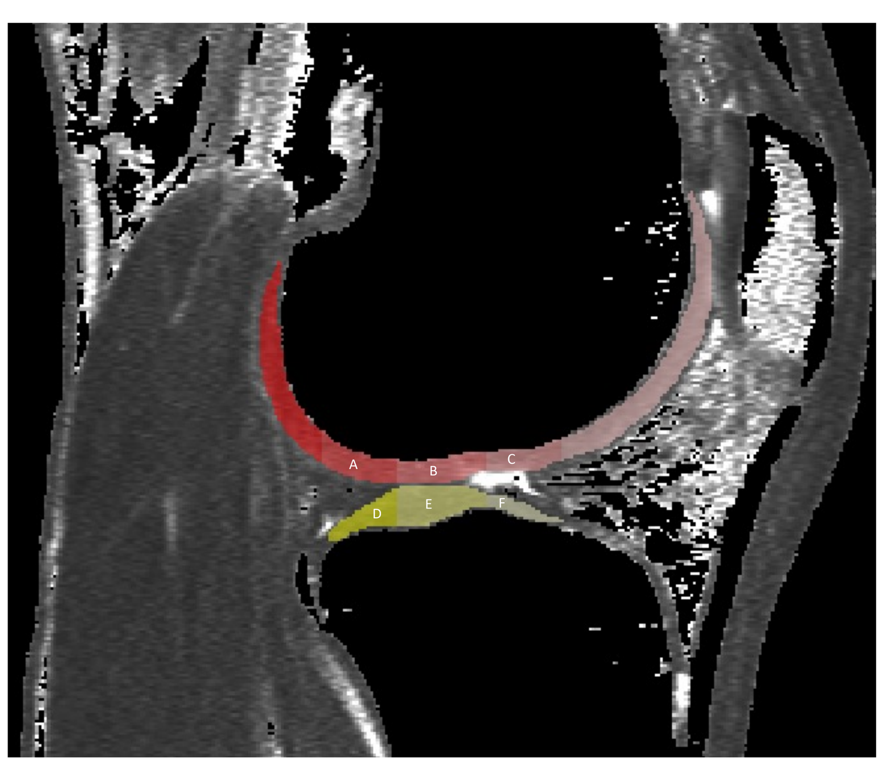


Figure 2. Segmented T1ρ relaxation map of the lateral regions of the posterior femur (A), middle femur (B), anterior femur (C), posterior tibia (D), middle tibia (E), and anterior tibia (F).

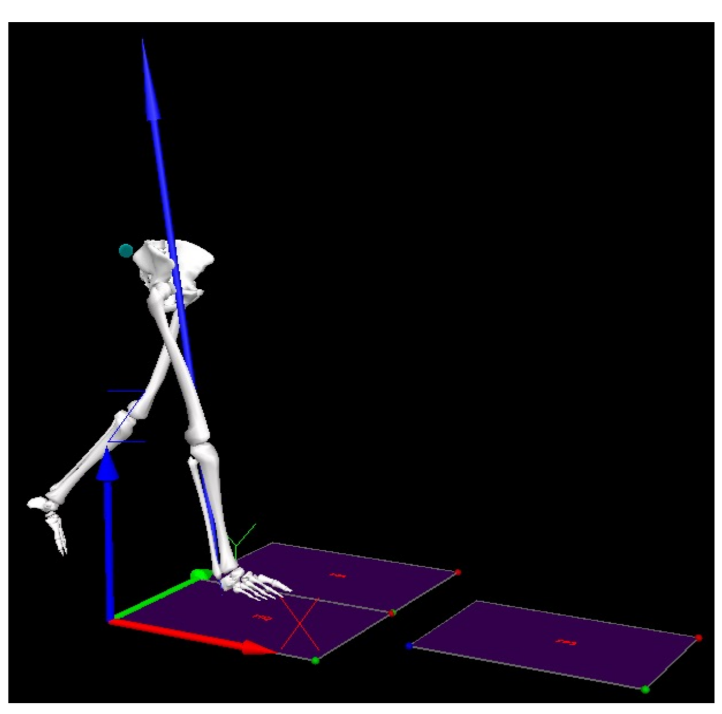


Figure 3. Visual-3D biomechanical analysis of a walking trial.

Biomechanical Data

- 13 participants completed walking trials at their preferred speed with a 10-camera motion capture system
- Visual 3D software was used to calculate vGRF values for the injured knees, with these values being normalized to body weight in Newtons (Figure 3)
- Peak vGRF, vGRF instantaneous loading rate, and vGRF linear loading rate were calculated (Figure 4)
- Partial Pearson correlations (controlling for preferred gait speed) were performed

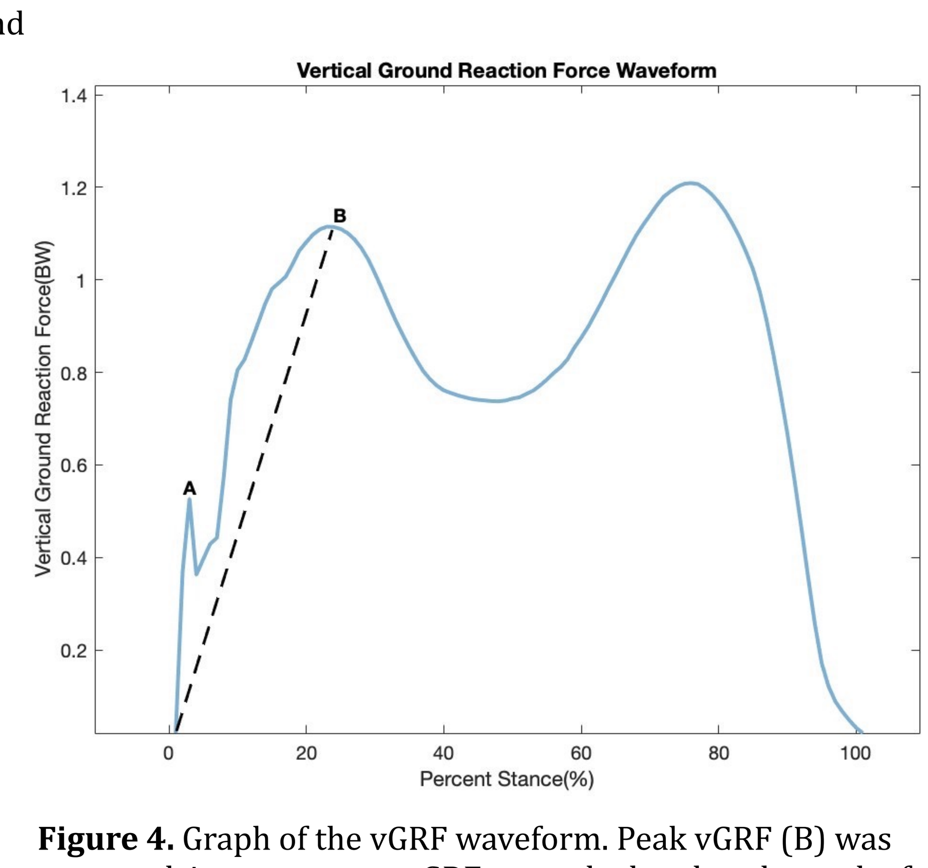
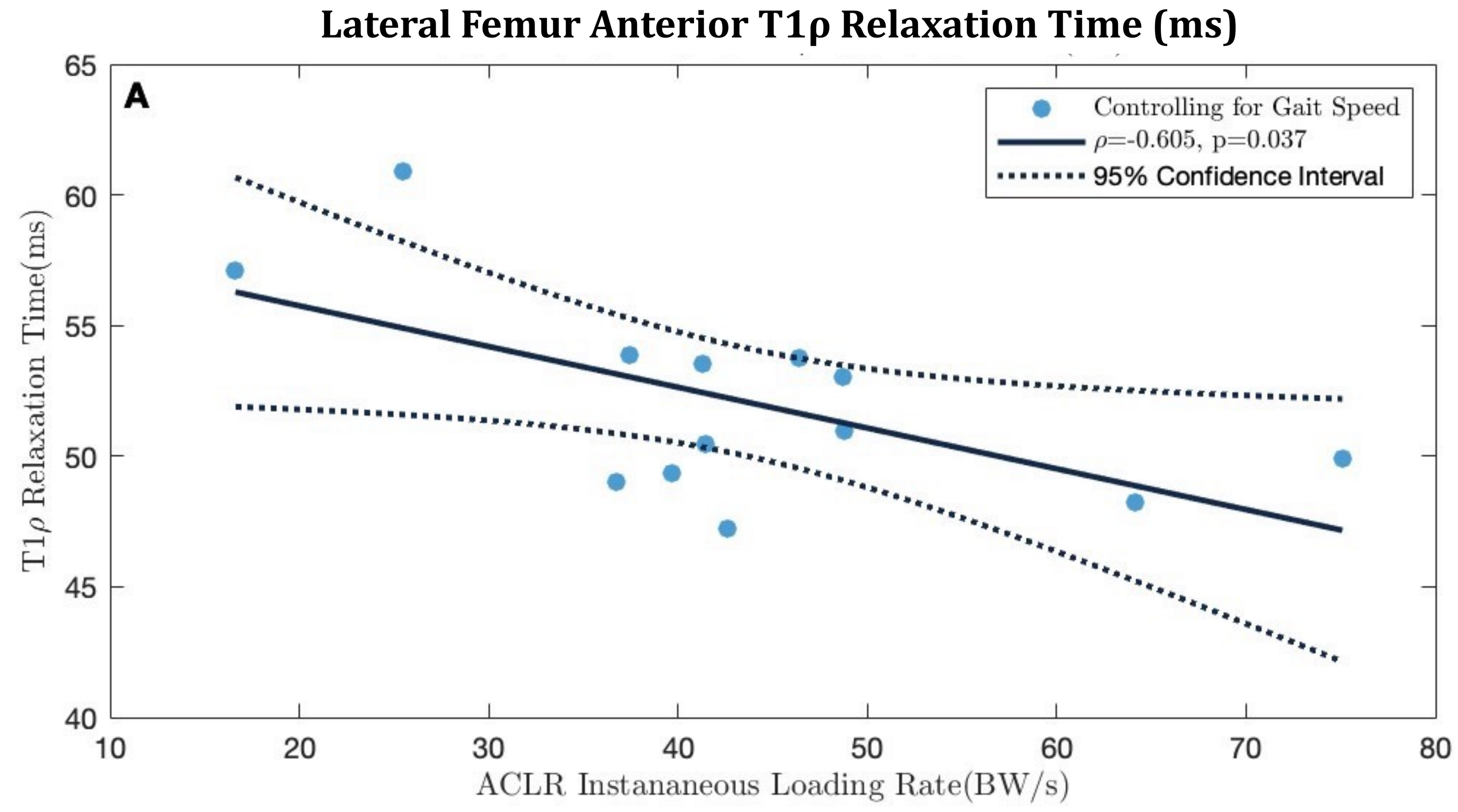


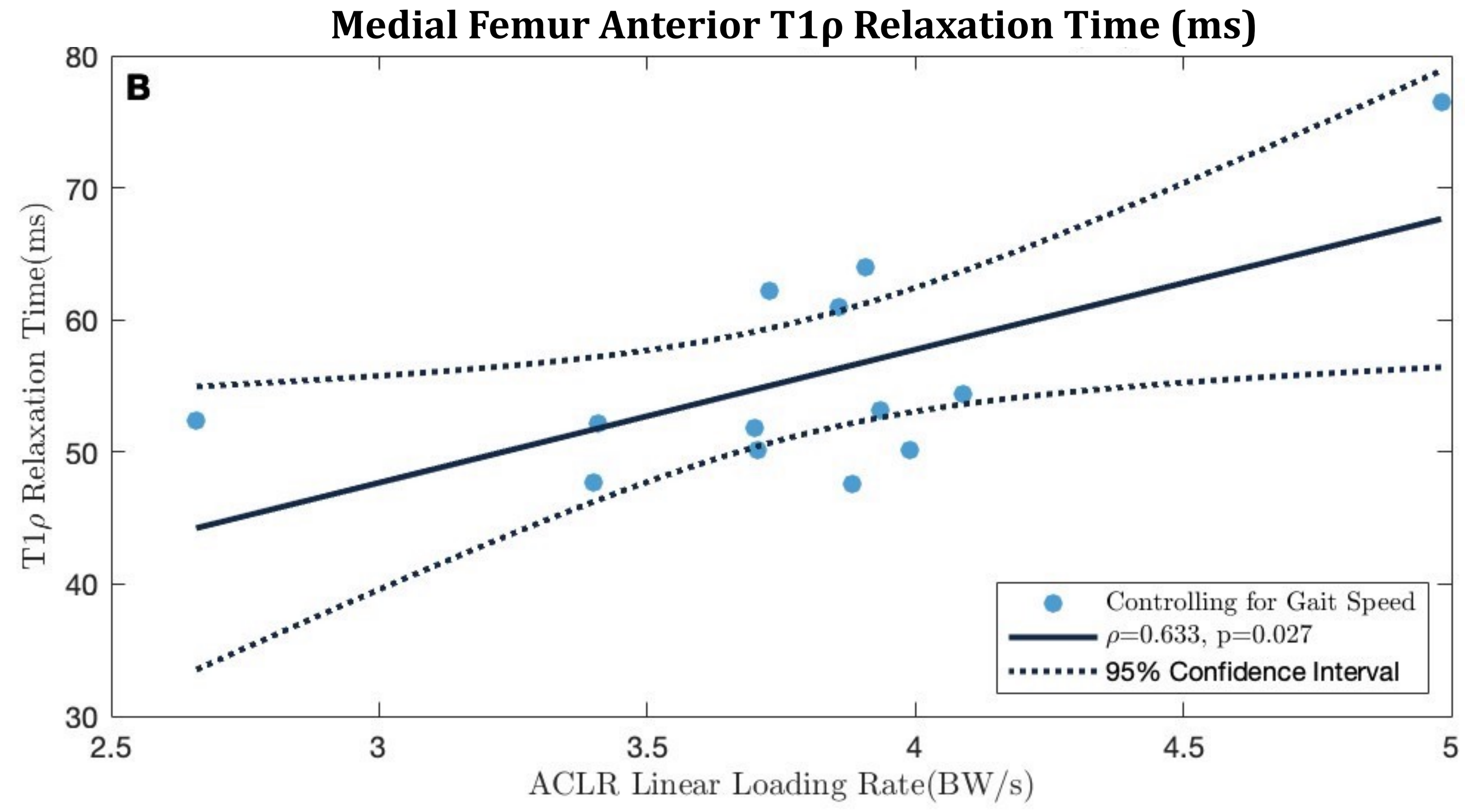
Figure 4. Graph of the vGRF waveform. Peak vGRF (B) was extracted, instantaneous vGRF was calculated as the peak of the first derivative from heel strike to A, and linear vGRF loading rate (dashed line) was calculated from heel strike to peak (B).

Results

Lateral Femur Anterior T1ρ Relaxation Time (ms)



Medial Femur Anterior T1ρ Relaxation Time (ms)



- Lesser vGRF instantaneous loading rates were associated with longer lateral femur anterior T1ρ relaxation times (r=-0.605, p=0.037)
- Lesser vGRF linear loading rates were associated with shorter lateral tibia posterior (r=0.628, p=0.038), lateral tibia anterior (r=0.654, p=0.021), medial femur middle (r=0.588, p=0.044), and medial femur anterior (r=0.633, p=0.027) T1ρ relaxation times
- T1ρ relaxation times had no significant correlation with preferred gait speed and peak vGRF (p>0.05)

Conclusion

- Lesser vGRF instantaneous loading rates were associated with longer T1ρ relaxation times
  - Supporting the hypothesis
- Lesser vGRF linear loading rates were associated with shorter T1ρ relaxation times
  - Contradicting the hypothesis
- Smaller vGRF instantaneous and linear loading rates influence femoral and tibial cartilage proteoglycan density differently in the ACLR limb
- The findings suggest that differential limb loading may result in contradicting affects on the cartilage

Future Plans

- Contradicting results – another analysis with a larger sample size
- Include 6 and 12 month post-ACLR time point data – longitudinal analysis
- Include T2 relaxation times which correspond to altered collagen content and organizational changes, another crucial part of cartilage degradation[3]

References

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Acknowledgements

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