An Exploratory Analysis of Changes in Tibiofemoral Joint Contact Forces Between 6-12 Months Following an Anterior Cruciate Ligament Reconstruction

[1]Nicolai Escobal , [1]Elizabeth Bjornsen, [2]Amanda, Munsch, [2]Jason Franz, [1]Brian Pietrosimone

[1]Department of Exercise and Sports Science, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
[2]Joint Department of Biomedical Engineering , University of North Carolina at Chapel Hill, and University of North Carolina State University, North Carolina

BACKGROUND

- 100,000-200,000 anterior cruciate ligament (ACL) tears occur in the US annually and 80% of those individuals will develop osteoarthritis between 5-15 years after the ACL injury and/or reconstruction (ACLR).[1,2]
- After ACLR, individuals demonstrate aberrant limb-level and joint-level loading profiles.[4]
- Lesser peak vertical ground reaction force (vGRF; i.e. limb-level loading) has been linked to worse patient-reported outcomes, worse cartilage composition, and worse cartilage metabolism.[5]
- Traditional biomechanical analyses are limited in the ability to account for individualized contributions of muscles surrounding the knee joint.
- Modeling technique that simulate joint contact force magnitudes provide a detailed analysis of the force the knee may experience during dynamic activities.
- However, it is unclear if joint-level loading magnitudes change within the first 12 months post-ACLR.[7]

PURPOSE

Purpose: To determine the effect sizes of simulated, peak medial and lateral tibiofemoral joint contact forces between 6 and 12 months following ACLR.

Hypothesis: We hypothesize that the medial and lateral tibiofemoral contact force magnitudes will differ at the 6-month and 12-month timepoints.

METHODS

Participants:
- The current study is a part of a larger, ongoing longitudinal cohort study.
- Participants were between 18 and 31 years of age and were recruited within 6 weeks of primary ACL tear. All participants underwent unilateral arthroscopic bone-patellar-tendon bone autograft ACLR.
- Demographic data, including Tegner Activity Score, age, body mass index, gait speed and the Knee Osteoarthritis Outcome Score (KOOS) quality of life subscale were reported.

Gait Biomechanics Collection and Knee Joint Contact Force Simulation:
- All participants performed a gait biomechanical analysis at 6- and 12- months post-ACLR.
- Kinetic and kinematic data were collected at 1200Hz and 120Hz respectively (Vicon, Denver, Colorado)[6]
- Marker trajectories were collected and scaled to create an individualized musculoskeletal model in OpenSim, a software system for biomechanical modeling, simulation, and analysis.
- Concurrent Optimization of Muscle Activations and Kinematics (COMAK) is an algorithm that was used to concurrently solve for knee kinematics, soft tissue (i.e. muscle, ligament, tendon) and articular cartilage contact loading.

Statistical Analysis:
- Hedge's g effect sizes were calculated between the 6- and 12-month timepoints in the medial and lateral compartments.
- R studio was used to generate graphs and figures to display the relationships between the 6 month and 12-month effect sizes as well as construct 95% confidence intervals (CI) around group means.

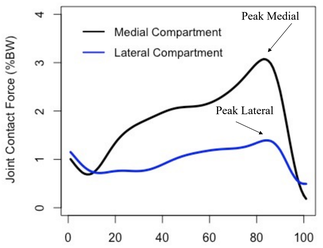

Figure 3. Medial and lateral compartment joint contact force profiles normalized to (%BW) and the stance phase of walking.

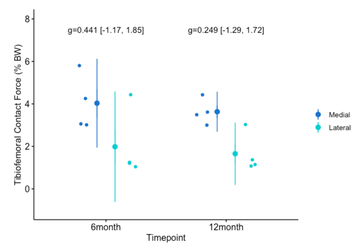

Figure 4. Peak Tibiofemoral Contact Forces in the medial and lateral compartment at the 6- and 12-month periods. Hedge's g effect sizes and associated 95% confidence intervals are displayed above the timepoints.

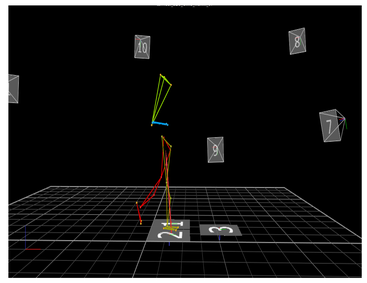

Figure 1.
Displays a 3D model of marker trajectories and ground reaction forces collected in Vicon Nexus.

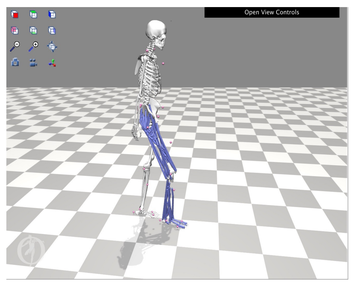

Figure 2.
Displays a 3D musculoskeletal model visualized in OpenSim.

RESULTS

TABLE 1. Descriptive Statistics (Mean ± SD)

Time Point	6 Months	12 Months
Age (yrs.)	22.25 ± 5.97	22.25 ± 5.97
BMI	24.88 ± 2.27	25.94 ± 0.88
Tegner Score	6.75 ± 2.06	10 ± 0
KOOS Quality of Life	56.25 ± 11.41	82 ± 22.46
Walking Speed (m/s)	1.21 ± 0.14	1.25 ± 0.21

- In our exploratory analysis, we analyzed a total of 4 participates , 2 males (50%) and 2 females (50%).
- The medical contact forces between 6 and 12 months had a Hedges g effect size of (0.441) with a 95% confidence interval lower limit of -1.17 and an upper limit of 1.85.
- The lateral contact forces between 6 and 12 months had a 95% Hedges g effect score of (0.249) with a 95% confidence interval lower limit of -1.29 to an upper limit of 1.72.
- The average, within-subject contact force magnitude decreased between 6 and 12 months in the medial (-0.399 ± 1.48) and lateral compartments (-0.329 ± 2.08).

DISCUSSION

Key Take-A-Ways:
- Medial and lateral contact force magnitudes may differ between 6-month and 12-month timepoints after ACLR.
- Contact force magnitudes at 12-month period tended to be slightly lower than 6-month timepoints.
- Between-subject variability in contact force magnitude over the assessed timepoint was identified.
- There was significant greater force on the medial tibiofemoral compared to the lateral and 3 out of 4 subjects had a decrease in medial contact forces from the 6–12-month periods.

Limitations:
- A small subgroup of individuals (n=4) was utilized for the analysis.
- The model used in our analysis was based on the anatomy and physiology of a young healthy female for all trials.

Future Directions:
- The analysis should be replicated in larger samples between 6- and 12-month period.
- Future research should determine the impact of muscle composition and muscle strength on changes in the contact force magnitudes between 6 to 12 month in ACLR individuals.

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