Full length article

Partial medial meniscectomy leads to altered walking mechanics two years after anterior cruciate ligament reconstruction: Meniscal repair does not

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A B S T R A C T

Background: Partial meniscectomy dramatically increases the risk for post-traumatic, tibiofemoral osteoarthritis after anterior cruciate ligament reconstruction (ACLR). Concomitant medial meniscus surgery influences walking biomechanics (e.g., medial tibiofemoral joint loading) early after ACLR; whether medial meniscus surgery continues to influence walking biomechanics two years after ACLR is unknown.

Research question: Does medial meniscus treatment at the time of ACLR influence walking biomechanics two years after surgery?

Methods: This is a secondary analysis of prospectively collected data from a clinical trial (NCT01773317). Fifty-six athletes (age 24 ± 8 years) with operative reports, two-year biomechanical analyses, and no second injury prior to two-year testing participated after primary ACLR. Participants were classified by concomitant medial meniscal status: no medial meniscus involvement (n = 36), partial medial meniscectomy (n = 9), and medial meniscus repair (n = 11). Participants underwent biomechanical analyses during over-ground walking including surface electromyography; a validated musculoskeletal model estimated medial compartment tibiofemoral contact forces. Gait variables were analyzed using 3 × 2 ANOVAs with group (medial meniscus treatment) and limb (involved versus uninvolved) comparisons.

Results: There was a main effect of group (p = .039) for peak knee flexion angle (PKFA). Participants after partial medial meniscectomy walked with clinically meaningfully smaller PKFAs in both the involved and uninvolved limbs compared to the no medial meniscus involvement group (group mean difference [95%CI]; involved: −4.9°[−8.7°, −1.0°], p = .015; uninvolved: −3.9°[−7.6°, −0.3°], p = .035) and medial meniscus repair group (involved: −5.2°[−9.9°, −0.6°], p = .029; uninvolved: −4.7°[−9.0°, −0.3°], p = .038). The partial medial meniscectomy group walked with higher involved versus uninvolved limb medial tibiofemoral contact forces (0.45 body weights, 95% CI: −0.01, 0.91 BW, p = 0.053) and truncated sagittal plane knee excursions, which were not present in the other two groups.

Significance: Aberrant gait biomechanics may concentrate high forces in the antero-medial tibiofemoral cartilage among patients two years after ACLR plus partial medial meniscectomy, perhaps explaining the higher osteoarthritis rates and offering an opportunity for targeted interventions.

Level of Evidence: Level III.

1. Introduction

Anterior cruciate ligament (ACL) injury rates are rising, particularly among young athletes involved in high-level sporting activities [1]. ACL injuries, unfortunately, often occur often in conjunction with injuries to other structures of the knee [2], with the menisci among the most commonly injured [2,3]. Meniscus injuries greatly elevate the risk for post-traumatic knee osteoarthritis [3], and partial meniscectomy at the time of ACL reconstruction (ACLR) is one of the strongest predictors of future early tibiofemoral osteoarthritis [3,4]. Evaluating factors that

may contribute to the development and progression of osteoarthritis after ACLR with meniscal involvement is critical to understanding the pathogenesis of post-traumatic osteoarthritis and creating targeted interventions to combat this debilitating disease.

Aberrant gait biomechanics are associated with the rapid development and progression of post-traumatic osteoarthritis after ACLR, particularly in the medial tibiofemoral compartment [5–7]. Partial medial meniscectomy may accelerate the development and progression of osteoarthritis via biomechanical changes. Medial meniscus treatment influences both walking biomechanics six months after ACLR [8] and

Table 1

There were no differences across groups in demographic characteristics, activity levels, graft type, lateral meniscus involvement, gait speed, or quadriceps strength index.

Table 1. Variable	No Medial Meniscus Involvement (N = 36)	Partial Medial Meniscectomy (N = 9)	Medial Meniscus Repair (N = 11)	P-value
Sex	18 F, 18 M	4 F, 5 M	2 F, 9 M	.174
Age (years)	23 ± 8	28 ± 12	23 ± 5	.266
BMI (kg/m^2)	26 ± 3	28 ± 3	27 ± 3	.097
Pre-Injury Sport Level	33 Level I, 3 Level II	8 Level I, 1 Level II	10 Level I, 1 Level II	.966
2-Year Sport/Activity Level	28 Level I, 3 Level II, 3 Level III, 1 Level IV, 1 No Data	8 Level I, 1 Level II	10 Level I, 1 Level III	.860
Graft Type	9 Allo, 12 BPTB, 15 HS	4 Allo, 1 BPTB, 4 HS	2 Allo, 3 BPTB, 6 HS	.543
Lateral Meniscus Involvement	21 none, 10 partial meniscectomy, 5 repair	2 none, 5 partial meniscectomy, 2 repair	7 none, 4 partial meniscectomy, 0 repair	.216
Numeric Pain Rating at 2 Years	0.2 ± 0.6	0.0 ± 0.0	0.0 ± 0.0	.338
Time from ACLR to 2-Year Testing (wks)	111 ± 15	111 ± 18	107 ± 4	.645
Gait Speed (m/s)	1.54 ± 0.11	1.47 ± 0.12	1.55 ± 0.07	.178
Quadriceps Strength Index (QI) at 2 Years (%)*	102.0 ± 13.0	93.6 ± 11.4	101.9 ± 13.2	.210

Abbreviations: BMI = body mass index; Level I sports involve jumping, pivoting, and hard cutting (e.g., basketball, football, soccer); Level II sports involve lateral motion but less jumping or hard cutting than level I (e.g., baseball/softball, racket sports, skiing); Level III activities include jogging, running, swimming, and light manual work; Level IV includes activities of daily living (and no sports); Allo = allograft; BPTB = bone-patellar tendon-bone autograft; HS = hamstring autograft; *Note: one participant in the No Medial Meniscus Involvement group did not undergo quadriceps strength testing at 2-years.

downhill running biomechanics two years after ACLR [9]. Meniscal pathology and partial medial meniscectomy may preferentially alter frontal plane walking biomechanics, especially knee adduction moments [8,10]. Higher and lower knee adduction moments have each been associated with OA development after partial meniscectomy [11] and ACLR [5], respectively, and adduction moments are widely used as surrogates for medial compartment tibiofemoral loading. Sagittal plane asymmetries, especially lower peak knee flexion moments, are likely the most ubiquitous biomechanical asymmetries among individuals in the first several years after ACLR [12], and patients with tibiofemoral osteoarthritis five years after ACLR walk using bilaterally smaller peak knee flexion angles (PKFAs) and moments compared to their non-osteoarthritic counterparts [6]. Therefore, evaluating knee kinematics, kinetics, and joint loading among individuals after ACLR with and without partial medial meniscectomy is essential to investigating the biomechanical pathway of accelerated osteoarthritis pathogenesis [13]. Previous work has not evaluated walking, the most common activity of daily living, at medium-term follow-up after ACLR while controlling for side of meniscal involvement.

Quadriceps femoris weakness is also associated with osteoarthritis after ACLR. Tourville and colleagues found a significant relationship between quadriceps strength both a few months and four years after ACLR and tibiofemoral joint space width narrowing, an indicator of osteoarthritis [14]. Limited evidence, however, suggests concomitant meniscal involvement after ACLR may not influence quadriceps strength [8,15–17] or activation [15]. These studies, however, did not account for the side of meniscus involvement [15–17] or required participants to meet stringent criteria, including 80% quadriceps strength index(QI), at the time of enrollment and quadriceps strength testing [8].

Aberrant gait biomechanics and/or quadriceps weakness may mediate the relationship between ACLR plus meniscectomy and the risk for osteoarthritis. Whether medial meniscus treatment continues to influence walking biomechanics two years after ACLR is unknown. Given that medial tibiofemoral osteoarthritis is more common than lateral tibiofemoral osteoarthritis [18], and previous work suggests that medial meniscus involvement [8,9], but not lateral meniscus involvement [9], may be related to altered biomechanics, we evaluated the impact of medial meniscus treatment on two key factors related to tibiofemoral osteoarthritis development: gait biomechanics and quadriceps strength. We included patient-specific electromyography-driven musculoskeletal modeling to provide a more informed estimate of medial tibiofemoral compartment contact force that incorporates

kinetics in multiple planes (i.e., knee adduction and flexion moments) [19]. The purposes of this study were to compare the effect of concomitant medial meniscus treatment with ACLR on walking biomechanics and, secondarily, QI two years after surgery. We hypothesized that patients after ACLR and concomitant partial medial meniscectomy would demonstrate altered walking biomechanics, including 1) knee kinematics, 2) knee kinetics, and 3) medial tibiofemoral contact forces, relative to patients after ACLR with no medial meniscus involvement or medial meniscus repair. We also hypothesized that there would be no differences between groups in QI.

2. Methods

2.1. Participants

This study is a secondary analysis of data collected prospectively for a clinical trial (NCT01773317). Institutional review board approval was obtained and all participants provided written informed consent or parental consent and patient assent if under age 18 years. Data were collected between September 2013 and August 2018 at the University of Delaware (Newark, DE). The parent trial inclusion/exclusion criteria were: regular (> 50 h/year) participant in level I or II sports (i.e., sports involving jumping, cutting, and/or pivoting) [20,21] prior to ACL injury and planning to return to sport; age 13–55 years at enrollment, which occurred 3–9 months after ACLR when patients achieved impairment resolution [22]; no history of previous ACLR and/or serious lower extremity injury to either limb; and no osteochondral defect > 1 cm^2. For the present study, participants were included only if they had an available operative report, underwent motion analysis testing two years after ACLR, and did not sustain a second injury prior to 2-year testing. Fifty-six athletes (age: 24 ± 8 years) met these criteria and were included in the present study. Participants were classified into three groups according to their concomitant medial meniscus status and treatment at the time of ACLR. The groups were: 1) No Medial Meniscus Involvement: no medial meniscus involvement or non-surgical management of a small, stable tear; 2) Partial Medial Meniscectomy; and 3) Medial Meniscus Repair (Table 1). Participants were collapsed across experimental conditions given no differences in clinical or functional outcomes or walking biomechanics [23–25] based on experimental group assignment.
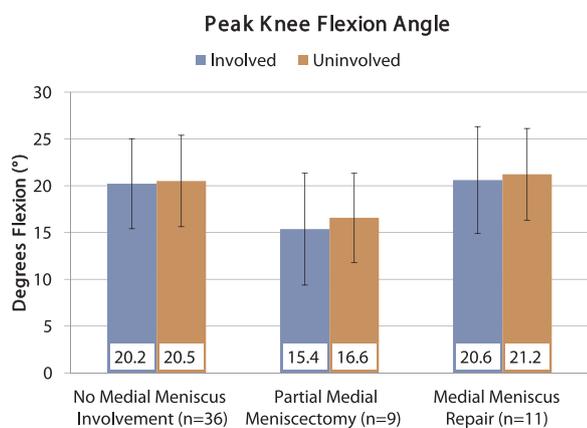
Peak Knee Flexion Angle

Fig. 1. There was a main effect of group (p = 0.039), with the partial medial meniscectomy group walking with smaller PKFAs. (See Table 2a-b for post-hoc comparisons.)

2.2. Biomechanical gait analyses

All participants completed motion analyses during over-ground walking a minimum of two years (mean ± standard deviation: 2.1 ± 0.3 years) after primary ACLR according to methods described previously [8]. Briefly, we cleaned and abraded the skin prior to placement of 7 electromyography (EMG) sensors (Motion Lab Systems, Baton Rouge, LA) per limb on the bilateral lower extremities (vastus medialis, vastus lateralis, rectus femoris, medial hamstrings, lateral hamstrings, medial gastrocnemius, and lateral gastrocnemius). Participants performed maximal volitional isometric contractions for each muscle group for EMG normalization purposes prior to placement of 39 retroreflective markers on the bilateral lower extremities. Participants walked over an embedded force platform (Bertec Coporation, Worthington, OH) at a self-selected speed (maintained within ± 5%). Kinematic data were captured with an 8-camera system (VICON, Oxford Metrics Limited, London, UK) at 120 Hz while kinetic and EMG data were collected at 1080 Hz. Commercial software (Visual3D, C-Motion, Germantown, MD) was used to calculate kinematics and kinetics. A validated, EMG-informed, patient-specific musculoskeletal model [26,27] was used to estimate medial compartment tibiofemoral contact force. The biomechanical variables of interest included: 1) knee kinematics: PKFA, knee flexion excursion during weight acceptance (i.e., initial contact to PKFA), and knee extension excursion during mid-stance (i.e., PKFA to peak knee extension angle); 2) knee kinetics: peak external knee flexion and adduction moments; and 3) peak medial

compartment tibiofemoral contact forces.

2.3. Quadriceps strength

We used an electromechanical dynamometer (Biodex Medical Systems, Shirley, NY) to evaluate quadriceps femoris strength. Participants completed approximately three trials per limb of maximal isometric quadriceps contractions with their knees secured at 90° flexion. A burst superimposition technique was used to ensure maximal contraction during each effort. We evaluated the uninvolved limb first followed by the involved limb, and calculated a QI using the highest volitionally achieved value in each, using the formula: QI = involved limb/uninvolved limb x 100(%).

2.4. Statistical analyses

We compared demographic and other patient characteristics using one-way analysis of variance (ANOVA) for continuous variables and Chi-Square tests of proportions for categorical values. Biomechanical variables were analyzed using a 3×2 mixed-model ANOVA with group (No Medial Meniscus Involvement, Partial Medial Meniscectomy, and Medial Meniscus Repair) and limb (Involved and Uninvolved) comparisons; secondary analyses using QI as a covariate were also conducted. Post-hoc analyses using the least significant difference method (equivalent to no adjustment) were used to avoid unnecessarily inflating risk of type II error [28]. Interlimb and group differences were compared to established minimal clinically important differences (MCIDs) [6,29] to determine whether differences were meaningful. Statistical analyses were conducted using SPSS Version 25.0(IBM Corporation, Armonk, New York, USA) with alpha set to 0.05.

2.5. Role of the funding sources

The funding sources had no involvement in the study design; collection, analysis, or interpretation of data; writing of the manuscript; or submission of the manuscript.

3. Results

3.1. Knee kinematics

There was a significant main effect of group (p = 0.039; p = 0.047 using QI as a covariate) for PKFA (Fig. 1). Participants after partial medial meniscectomy walked with smaller involved limb PKFAs compared to the no medial meniscus involvement and medial meniscus repair groups (post-hoc one-way ANOVA p = 0.039; Table 2a).

Table 2

a–b. Participants after partial medial meniscectomy walked with smaller involved limb peak knee flexion angles compared to the no medial meniscus involvement and medial meniscus repair groups (post-hoc one-way ANOVA p = 0.039; Table 2a). Participants after partial medial meniscectomy also tended to walk with smaller uninvolved limb PKFAs relative to the other two groups (post-hoc one-way ANOVA p = 0.071; Table 2b).

Table 2a. Involved Limb Post-Hoc Group Comparisons for PKFA.

Group A	Group B	Group Mean Difference (A - B) [95% CI]	P-Value*
Meniscectomy	No Involvement	−4.9° [−8.7°, −1.0°]	0.015^
Meniscectomy	Repair	−5.2° [−9.9°, −0.6°]	0.029^
Repair	No Involvement	0.4° [−3.2°, 4.0°]	0.832

Table 2b. Uninvolved Limb Post-Hoc Group Comparisons for PKFA.

Group A	Group B	Group Mean Difference (A - B) [95% CI]	P-Value*
Meniscectomy	No Involvement	−3.9° [−7.6°, −0.3°]	0.035^
Meniscectomy	Repair	−4.7° [−9.0°, −0.3°]	0.038^
Repair	No Involvement	0.7° [−2.6°, 4.1°]	0.668

Abbreviations: PKFA = peak knee flexion angle; CI = confidence interval. *P-values in the table reflect the least significant difference p-value for the post-hoc comparison of Groups A and B; ^p < 0.05.
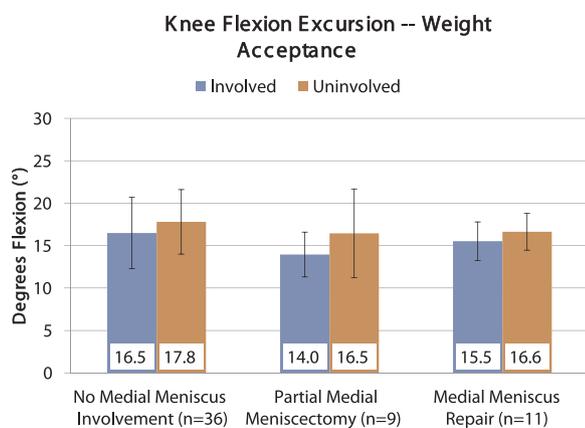
Fig. 2. There was a main effect of limb (p = 0.001) for knee flexion excursion during weight acceptance, however this relationship was moderated by QI and no interlimb difference in any group exceeded the minimal clinically important difference (MCID) value of 3˚ [29].

Participants after partial medial meniscectomy also tended to walk with smaller uninvolved limb PKFAs relative to the other two groups (post-hoc one-way ANOVA p = 0.071; Table 2b). The group differences in both the involved and uninvolved limbs among the partial medial meniscectomy patients and the other two groups exceeded the MCID value of 3˚ [29]. In contrast, no significant or meaningful [29] differences existed in either limb for the other groups.

There was a main effect of limb (p = 0.001), moderated by QI (p = 0.344 using QI as a covariate), characterized by smaller involved knee flexion excursions during weight acceptance; no group interlimb difference exceeded the MCID [29] (Fig. 2). There was a main effect of limb (p < 0.001) for knee extension excursion during mid-stance that was moderated by QI (p = 0.869), however only the partial medial meniscectomy group walked with meaningfully [29] smaller knee extension excursions (Fig. 3).

3.2. Knee kinetics

The main effect of limb had a p-value of 0.080 for peak knee flexion moment, however, this relationship was moderated by QI (p = 0.656) and only the partial medial meniscectomy group interlimb difference (-0.05 [95% CI: -0.20, 0.10] N*m/kg*m; Cohen's d effect size: -0.35) was clinically meaningful [29]. There were no statistically significant differences in peak knee adduction moment (interaction p = 0.217, limb p = 0.739, group p = 0.585). Participants in the partial medial
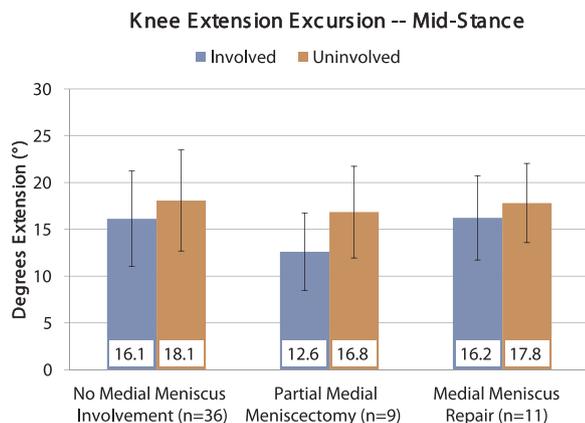

Fig. 3. There was a main effect of limb (p < 0.001) for knee extension excursion during mid-stance, however this relationship was moderated by QI and only the interlimb difference (4.2˚ less excursion in the involved limb) in the partial medial meniscectomy group was clinically meaningful [29].
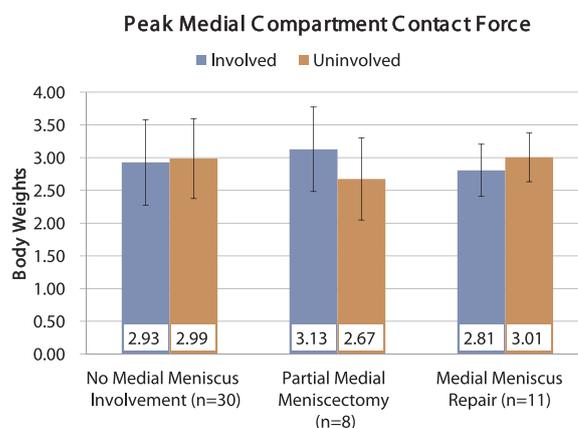

Fig. 4. There tended to be an interaction effect (p = 0.084) characterized by meaningfully [6] higher involved limb peak medial compartment contact forces in the partial meniscectomy patients but not in the other groups. (Note: there were 7 subjects for which data could not be modeled.)

meniscectomy group walked with higher involved limb peak knee adduction moments (mean interlimb difference [95% CI]: 0.04 [-0.07, 0.16] N*m/kg*m; Cohen's d effect size: 0.39) while those in the no involvement (-0.02 [-0.06, 0.03] N*m/kg*m; Cohen's d effect size: -0.19) and repair (-0.05 [-0.13, 0.04] N*m/kg*m; Cohen's d effect size: -0.46) groups did not.

3.3. Medial compartment tibiofemoral contact forces

The interaction effect had a p-value of 0.084 (p = 0.070 using QI as a covariate) for peak medial compartment contact force (PMCCF, Fig. 4). Participants in the partial medial meniscectomy group walked with higher involved versus uninvolved limb PMCCF (3.13 [2.70, 3.57] vs. 2.67 [2.27, 3.08] body weight [BW] units); the interlimb difference of 0.45 BW (95% CI: -0.01, 0.91 BW, p = 0.053) exceeded the meaningful interlimb difference threshold of 0.4 BW [6]. In contrast, interlimb differences in the no medial involvement and repair groups were not meaningful [6].

3.4. Quadriceps strength index (QI)

There were no significant differences in QI (p = 0.210, Table 1).

4. Discussion

The purposes of this study were to compare the effect of medial meniscus treatment on walking biomechanics and, secondarily, QI two years after ACLR. Our hypothesis that patients after ACLR plus partial medial meniscectomy would demonstrate altered walking biomechanics relative to patients after ACLR with no medial meniscus involvement or medial meniscus repair was supported. Our secondary hypothesis that there would be no differences between groups in QI was also supported statistically, although the clinically lower mean among the partial medial meniscectomy group warrants further discussion (below). Our key findings were that participants two years after ACLR plus partial medial meniscectomy walked using aberrant biomechanics (i.e., smaller PKFAs, asymmetrical knee extension excursions, and higher involved knee medial compartment tibiofemoral contact forces) that were not present among participants two years after ACLR with no medial meniscus involvement or medial meniscus repair. Our findings may help explain the greatly elevated risk of post-traumatic osteoarthritis among patients after ACLR with concomitant partial meniscectomy, and provide an area for developing targeted intervention strategies.

Our findings extend previous work that found biomechanical

differences among participants according to medial meniscus pathology and treatment [8–10,30]. Capin et al. found that patients early after ACLR with partial medial meniscectomy exhibit higher knee adduction moments in their involved limbs compared to those after ACLR with no medial meniscus involvement and with medial meniscus repair [8]. Akpinar and colleagues found greater anterior tibial translation during downhill running among those with ACLR and medial meniscus tears versus those with isolated ACLR or ACLR and lateral meniscus tears two years after ACLR [9]. Thorlund et al. found, among patients after isolated arthroscopic partial medial meniscectomy, peak knee adduction moments and impulses increased from before to 12 months after surgery [10]; and, Ren et al., found changes in three-dimensional knee kinematics and kinetics during level walking among ACL-deficient knees with medial meniscus tears compared to those without [30]. The present study indicates that aberrant walking biomechanics persist at least two years after ACLR with partial medial meniscectomy but not among those with no medial meniscus involvement or medial meniscus repair. Specifically, we found that individuals two years after ACLR with partial medial meniscectomy walked using bilaterally smaller PKFAs and, while not statistically different, clinically meaningful [6,29] asymmetries, including smaller knee extension excursions, smaller knee flexion moments, and higher joint contact forces in the involved limb. In contrast to previous work earlier after partial meniscectomy with [8] or without [10] ACLR, no group differences in peak knee adduction moment were present, although the numerically higher values in the involved (relative to the uninvolved) limb of the partial medial meniscectomy group (coupled with smaller sagittal knee angles) likely drove their asymmetrical tibiofemoral contact forces.

Our findings contrast with previous work by Hall and colleagues [31], which found no differences in knee gait biomechanics between individuals after ACLR with and without concomitant meniscal pathology. The contrasting findings are likely because their study [31] grouped all participants with meniscal pathology together, rather than accounting for the compartment of meniscal involvement and whether it was managed via partial meniscectomy or repair. Hall et al. also investigated participants over a wider range of time (12–24 months) [31] rather than at two years post-operatively, although given previous findings that gait biomechanics differ early after ACLR according to medial meniscus treatment [8], differences are likely to exist one year after ACLR as well.

The walking biomechanics exhibited by participants after ACLR plus partial medial meniscectomy may be especially detrimental to tibiofemoral cartilage health. Andriacchi and colleagues have posited that altered kinematics, such as those common after ACLR, distribute loads to cartilage regions that may be thinner and less habituated to attenuate loading, thereby initiating or accelerating osteoarthritis pathogenesis [13]. A recent study in a separate cohort of individuals five years after ACLR found that those with medial tibiofemoral radiographic osteoarthritis walked with bilaterally smaller PKFAs relative to those without radiographic osteoarthritis, which may have shifted the loading to the poorly conditioned anterior tibiofemoral cartilage [6]. Khandha et al. suggested that, among patients who developed osteoarthritis five years after ACLR, the uninvolved limb PKFA may have decreased to achieve "bad symmetry" by matching the involved limb PKFA; in contrast, among those without osteoarthritis, the involved limb PKFA may have increased to achieve "good symmetry," matching the uninvolved limb [6]. In the present study, patients after ACLR with partial medial meniscectomy walked using bilaterally smaller PKFAs, similar to the osteoarthritic patients in Khandha et al.'s cohort [6]. Patients after partial medial meniscectomy in the present study also walked with truncated knee excursions and higher medial tibiofemoral joint loading. The combination of higher loads on thinner, unhabituated cartilage may be a dangerous combination that predisposes to early osteoarthritis. Future studies could consider evaluating split-belt treadmill training paradigms to address biomechanical asymmetries and perhaps bilateral speed and/or loading manipulations for individuals with bilaterally

aberrant biomechanics (i.e., smaller knee flexion angles).

The mean QI of 93.6% in the partial medial meniscectomy group was lower than in the no medial meniscus involvement (102%) or medial meniscus repair (101.9%) groups. Exploratory analyses revealed that 44.4% (4/9) of the partial meniscectomy participants failed to achieve the widely accepted symmetry index threshold of 90% [22,32,33], while just 14.2% (5/35) and 18.2% (2/11) of no involvement and repair participants, respectively, failed to achieve this threshold. Moreover, recent evidence suggests that 90% strength symmetry index may be insufficient for restoring function and preventing future injury [34], and higher values like 95%, which only the partial medial meniscectomy group did not achieve, may be more appropriate. Our findings contrast with prior work that has found no meaningful differences in quadriceps strength [8,15–17] or activation [15] among patients after ACLR according to concomitant meniscal involvement. These studies, however, did not account for the side of meniscus involvement [15–17], included patients with multi-ligament injuries [17] or articular cartilage damage [16], or required participants to meet stringent criteria, including 80% QI, at the time of enrollment and quadriceps strength testing [8]. Future investigations are warranted.

To the study's merit, we used comprehensive walking analyses including electromyography and a validated musculoskeletal modeling approach [26,27] to estimate medial compartment loading that cannot be measured directly in vivo. We also had a relatively homogenous cohort as we excluded for previous ACLR, concomitant grade III ligamentous injury, or osteochondral defects $> 1cm^2$, although we included multiple graft types (no difference between groups). We did not use musculoskeletal imaging to evaluate for osteoarthritis or meniscus status at the 2-year gait analysis, although the higher prevalence of osteoarthritis after ACLR with partial meniscectomy is well-documented. The groups were not equal in size, although they were not different across numerous demographic characteristics. Given the modest sample sizes and desire to avoid unnecessarily inflating risk of type II error, we did not perform post-hoc corrections [28]; to account for type I error risk, we compared differences to established MCIDs [6,29]. Finally, we did not control for graft type or lateral meniscus involvement, although neither differed among groups, and our results may only be generalizable to younger athletes.

In summary, patients two years after ACLR with concomitant partial medial meniscectomy walked using bilaterally smaller PKFAs and exhibited gait asymmetries, especially smaller involved knee extension excursion and higher involved medial tibiofemoral joint contact forces, that were not present among participants two years after ACLR with no medial meniscus involvement or concomitant medial meniscus repair. These aberrant gait biomechanics may concentrate higher forces in the antero-medial tibiofemoral cartilage [6,13], providing a plausible mechanism explaining the higher osteoarthritis rates among patients two years after ACLR plus partial medial meniscectomy. Patients after ACLR plus partial medial meniscectomy also had clinically lower QI. Our findings may inform future, targeted interventions to ameliorate aberrant movement patterns among patients after ACLR and concomitant partial medial meniscectomy.

Statement of clinical significance

Aberrant gait biomechanics persist two years after ACLR with partial medial meniscectomy but not in those two years after ACLR with medial meniscus repair or no medial meniscus involvement. These aberrant gait biomechanics may concentrate high forces in the antero-medial tibiofemoral cartilage among patients two years after ACLR plus partial medial meniscectomy, perhaps explaining the higher osteoarthritis rates and offering an opportunity for targeted interventions.

Author contributions

JJC contributed to conception and design, data acquisition, data

Declaration of Competing Interest

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