Early Sagittal Knee Biomechanics Differ in Individuals With and Without Knee-Related Symptoms 12 Months Following Anterior Cruciate Ligament Reconstruction

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INTRODUCTION: Aberrant gait biomechanics are observed in individuals in the first 6-12 months following anterior cruciate ligament reconstruction (ACLR) as compared to matched uninjured controls and are associated with knee osteoarthritis (OA) development and clinically significant knee-related symptoms. A common, aberrant biomechanical profile present during the first 12 months post-ACLR and related to poor knee-related outcomes following ACLR, is a persistent stiffened knee strategy. This strategy is characterized by lesser peak knee extension moment (KEM) and peak knee flexion angle (KFA), resulting in lesser knee range of motion (ROM), within the first 50% of stance during gait. Furthermore, a stiffened knee strategy may result in more localized loading of tibiofemoral tissues and thereby hastening joint tissue breakdown. Though a stiffened knee strategy is commonly observed throughout the first 12 months post-ACLR, it is unknown if those who report persistent knee-related symptoms exhibit a more profound stiffened knee strategy within the first 6 months post-ACLR. Therefore, the purpose of this study was to compare KFA, KEM, and knee ROM throughout stance phase at 2, 4, and 6 months post-ACLR between individuals with and without knee-related symptoms at 12 months post-ACLR. We hypothesized that symptomatic individuals exhibit a more profound stiffened knee strategy (i.e., lesser KFA, KEM, knee ROM) compared to asymptomatic individuals early post-ACLR.

METHODS: Gait biomechanics of individuals with primary ACLR were collected at 2, 4, and 6 months post-ACLR. Gait analysis was performed barefoot at each participant's habitual walking speed using a 3-D motion capture system. KFA and KEM were extracted throughout stance phase, defined as heel strike to toe-off, and time-normalized to 101 data points (0-100%). Knee ROM was calculated from heel strike to minimum knee flexion at midstance. Patient-reported outcomes of the Knee Injury and Osteoarthritis Outcome Score (KOOS) were recorded 12 months post-ACLR. Participants were retrospectively assigned to either a symptomatic or asymptomatic group depending on their KOOS outcomes utilizing the Englund et al. (2003) definition. We conducted separate functional waveform analyses to compare KFA and KEM between the symptomatic and asymptomatic groups at 2, 4, and 6 months post-ACLR and included gait speed as a covariate in the analysis. Knee ROM, gait speed, KOOS and anthropometric data were compared between groups using separate Mann-Whitney U tests (α=0.05).

RESULTS SECTION: The symptomatic group demonstrated greater KFA during early stance (0-17%, A.1, A.4) and lesser KFA at late stance (95-100%, A.1, A.4) at 2 months, greater KFA at early to mid-stance (0-23%, 33-44%, A.2, A.5) at 4 months as well as greater KFA (0-44%, A.3, A.6) from early to mid-stance at 6 months post-ACLR. The symptomatic group also demonstrated greater KEM throughout early to late stance (22-29%, 37-51%, 54-73%, 80-99%, B.2, B.5) at 4 and 6 months (11-40%,87-96%, B.3, B.6) post-ACLR. No differences in knee ROM were observed between groups at any time point.

DISCUSSION: Contrary to our hypothesis, the symptomatic group walked with an overall more flexed knee and greater KEM during multiple portions of the first half of stance, despite demonstrating a similar overall knee ROM as the asymptomatic group. Differences in KFA and KEM seem to increase over time between groups. Greater KFA and KEM throughout stance may lead to more localized loading of the posterior articular cartilage regions over time. It remains unknown if changes in KFA and KEM contribute to changes in knee OA disease status and worse knee-related symptoms 12 months post-ACLR.

SIGNIFICANCE/CLINICAL RELEVANCE: Our results indicate that sagittal knee biomechanics as early as 2 months post-ACLR are linked to knee-related symptoms 12 months post-ACLR. Though differences in KFA and KEM between groups are minimal at 2 months, they may become more apparent at 6 months post-ACLR.

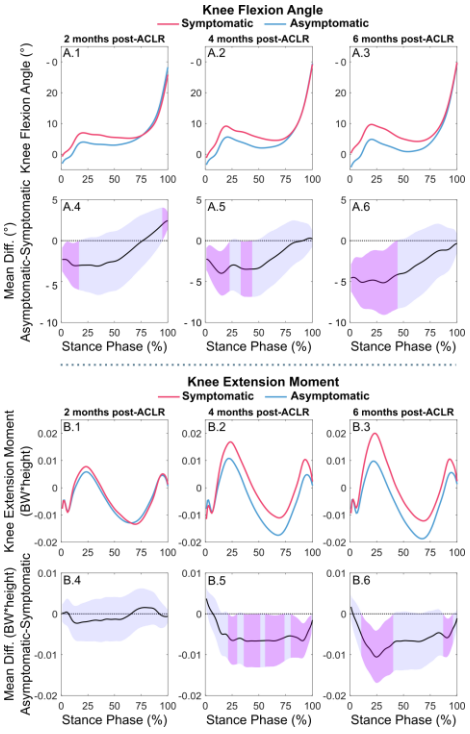

Figure 1: Knee flexion angle (A.1-A.3) and knee extension moment waveforms (B.1-B.3) with corresponding mean differences (A.4-A.6, B.4-B.6) and 95% confidence intervals (light blue) between the symptomatic and asymptomatic groups at 2, 4, and 6 months post-ACLR. Areas with significant differences between waveforms are highlighted in purple and are defined as areas in which the 95% confidence interval of the mean differences do not include zero.

Table 1: Anthropometric data of the symptomatic and asymptomatic groups

		Symptomatic	Asymptomatic
N (female/male)	2 months	9 (6/3)	26 (17/9)
	4 months	7 (4/3)	26 (17/9)
	6 months	5 (3/2)	27 (18/9)
Age (y)		22.7±3.1*	19.9±3.2
BMI (kg·m^{-2})		24.6±2.3	23.7±3.7
KOOS 12 months	QOL	50.0±17.7*	79.6±17.9
	Symptoms	68.7±11.3*	89.2±6.1
	Pain	80.7±8.0*	95.3±4.1
	ADL	94.4±9.0*	99.5±0.8
	Sport	57.2±25.1*	93.5±7.0
Gait speed (m·s^{-1})	2 months	1.1±0.2	1.1±0.1
	4 months	1.3±0.1*	1.2±0.1
	6 months	1.3±0.0	1.2±0.1
Knee ROM (°)	2 months	10.3±4.9	11.1±4.2
	4 months	16.0±4.6	14.2±5.2
	6 months	15.5±2.4	15.0±5.8

BMI – body mass index, KOOS – Knee Injury and Osteoarthritis Outcome Score, ROM – range of motion; *significant difference ($p \leq .05$)