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The knee extension moment during gait is more than two times lower after a total knee arthroplasty

A comparison to asymptomatic controls at matched walking speeds

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Results: A decrease in KFE in the injured limb from 6 to 12 months post-ACLR significantly associated with greater T1ρ ILR for Global-LTC (ΔR^2=.20, β=-.46, P=.02) as well as the Posterior-LTC (ΔR^2=.21, β=-.47, P=.02) and Central-LTC ROI (ΔR^2=.24, β=-.51, P=.01) 12 months post-ACLR. Similarly, a decrease in KFE in the uninjured limb from 6 to 12 months post-ACLR significantly associated with greater T1ρ ILR for Global-LFC (ΔR^2=.19, β=-.45, P=.03) as well as the Posterior-LFC (ΔR^2=.43, β=-.69, P=.01) 12 months post-ACLR. A decrease in peak KFA in the injured limb from 6 to 12 months post-ACLR significantly associated with greater T1ρ ILR for the Central-LFC (ΔR^2=.21, β=-.47, P=.04), as well as the Global-LTC (ΔR^2=.17, β=-.43, P=.04) and the Central-LTC (ΔR^2=.24, β=-.51, P=.01) 12 months post-ACLR. Similarly, a decrease in peak KFA in the uninjured limb from 6 to 12 months post-ACLR significantly associated with greater T1ρ ILR for the Central-LFC (ΔR^2=.28, β=-.55, P=.01) 12 months post-ACLR.
Conclusions: Decreases in peak KFA for the injured limb and KFE for both limbs from 6 to 12 months post-ACLR associate with greater T1ρ ILR in the lateral tibiofemoral compartment at 12 months post-ACLR. These data suggest individuals who adopt a stiffened knee strategy early post-ACLR may also exhibit changes in cartilage composition. Decreases in knee joint kinematics during walking may reduce an individual's ability to attenuate force at the knee. This may lead to altered loads distributed through the lateral tibiofemoral joint, which may relate to potential deleterious compositional changes to the articular cartilage. Future work should investigate if using novel rehabilitation techniques to increase peak KFA and KFE during walking post-ACLR influences compositional changes in cartilage of the lateral tibiofemoral compartment.

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VIBRATORY STIMULI IMPROVE GAIT BIOMECHANICS LINKED TO POST-TRAUMATIC OSTEOARTHRITIS IN INDIVIDUALS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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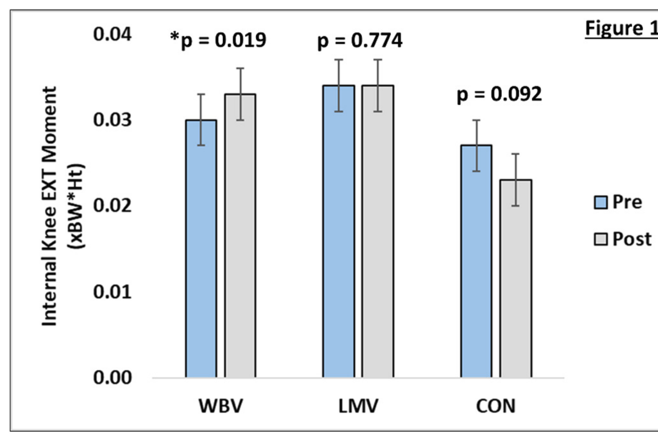
Purpose: Post-traumatic knee osteoarthritis (PTOA) is a common complication following anterior cruciate ligament reconstruction (ACLR). While the causes are poorly understood, aberrant gait biomechanics have received considerable attention in the literature. High-rate loading disrupts cartilage structure and biosynthesis in animal models, and has been identified during walking gait in the ACLR limb compared to the contralateral limb and healthy controls. Additionally, individuals who develop PTOA 5 years post-ACLR demonstrate lesser peak knee flexion angles and sagittal plane moments, and trend toward lower frontal plane moments during gait compared to those without PTOA. These aberrant gait biomechanics are influenced by quadriceps dysfunction, with higher loading rates and lower sagittal plane moments being associated with poorer quadriceps function. Vibratory stimuli improve quadriceps function in individuals with ACLR, potentially representing a viable rehabilitation approach for reducing PTOA risk. Therefore, the purpose of this investigation was to evaluate the effects of vibratory stimuli on gait biomechanics linked to PTOA development in individuals with ACLR.
Methods: Three-dimensional gait biomechanics were sampled in 73 individuals with unilateral ACLR (53 females, 20 males; age = 21 ± 3 years; time since ACLR = 27 ± 16 months) immediately prior to and following 1 of 3 interventions. Subjects walked barefoot at their preferred speed which was maintained across trials and testing sessions via infrared timing gates. Subjects were randomized to receive one session of whole body vibration (WBV; n = 25), local muscle vibration (LMV; n = 24), or control/no vibration (CON; n = 24) interventions. Gait biomechanics outcomes were assessed during the weight acceptance phase (i.e. 1^{st} 50% of stance), and included the peak magnitude of the vertical ground reaction force (vGRF) and its instantaneous loading rate (i.e. 1^{st} time derivative), peak internal knee extension and valgus moments (i.e. internal resistance to external flexion and varus loading, respectively), and peak knee flexion and varus angles. The effects of the interventions were evaluated via 3(Group: WBV, LMV, CON) x 2(Test: Pre, Post) repeated measures ANCOVA controlling for gait speed. EMG data were also sampled from the quadriceps during gait, and mean quadriceps EMG amplitude during the weight acceptance phase was evaluated as an explanatory contributor to any observed changes in gait biomechanics.

Results: Vibration did not influence the peak vGRF magnitude (p = 0.189) or loading rate (p = 0.964), the peak internal knee valgus moment (p = 0.464), or the peak knee flexion (p = 0.526) or varus (p = 0.351) angles. However, the Group x Time interaction effect was significant for the peak internal knee extension moment (p = 0.012), and *post hoc*analyses indicated an increase with WBV (p = 0.019), but no changes with LMV (p = 0.774) or CON (p = 0.092) (Figure 1). Additionally, quadriceps EMG amplitude increased with WBV (51 vs. 55 % max, p = 0.014).
Conclusions: A single session of WBV acutely increased quadriceps activity and the internal knee extension moment during walking. Individuals who develop PTOA within 5 years following ACLR display lower sagittal plane moments during gait compared to those who do not develop PTOA. Additionally, sagittal plane moments are smaller in individuals with severe vs. moderate knee OA and healthy controls, and in individuals with symptomatic knee OA compared to those who are asymptomatic but display the same severity of radiographic knee OA. The improvements in quadriceps EMG activity and sagittal plane moment resulting from WBV suggest that adding vibration to ACLR rehabilitation represents a plausible strategy for improving quadriceps function and reducing PTOA risk. Future research is necessary to elucidate the neuromechanical contributors to these improvements in gait biomechanics and to determine if vibration integrated into traditional ACLR rehabilitation influences the risk of PTOA.



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THE KNEE EXTENSION MOMENT DURING GAIT IS MORE THAN TWO TIMES LOWER AFTER A TOTAL KNEE ARTHROPLASTY. A COMPARISON TO ASYMPTOMATIC CONTROLS AT MATCHED WALKING SPEEDS

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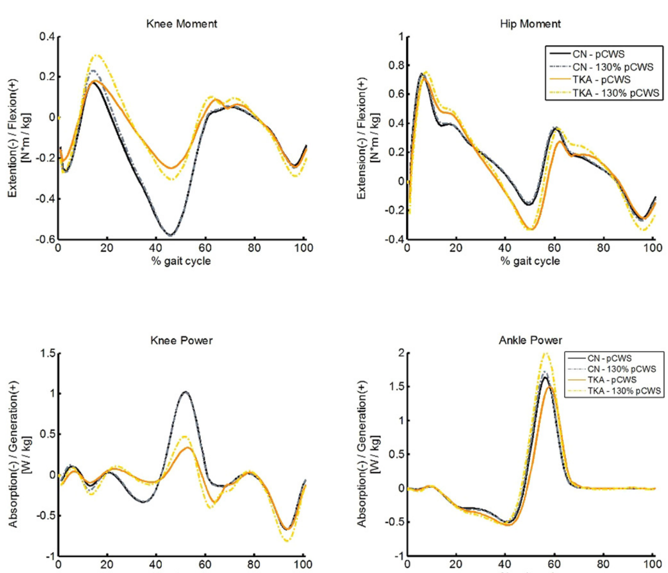
Purpose: Total knee arthroplasty (TKA) is a successful treatment in decreasing pain and increasing functional capacity for end-stage knee osteoarthritis. However, even up to 10 years after TKA, patients show a slower and different gait pattern compared to asymptomatic age-matched controls.Previous studies have shown differences in kinematic and kinetic variables between TKA patients and asymptomatic controls at comfortable walking speed (CWS). However, since TKA patients walk at lower CWS than controls, it is difficult to conclude whether the differences in kinetic variables observed are gait adaptations related to the TKA or due to differences in walking speed. Therefore, to be able to identify deviating biomechanics not related to differences in gait speed, it is important to match walking speed of TKA patients and asymptomatic controls.The aim of this study was to identify differences in kinetic variables between TKA patients and asymptomatic controls at matching walking speeds.
Methods: 18 patients (6 men) that have undergone TKA surgery more than 1 year ago were included (age 68.5±2.7). All patients were 1-to-1 matched to an asymptomatic control based on age, gender and BMI. Kinetic data of their gait were collected. Patients walked at comfortable walking speed (CWS) and 130% CWS, to challenge the gait of patients. Asymptomatic controls walked at CWS and 4 fixed speeds, which

Table 1 Peak values sagittal knee and hip moments during late stance at patient CWS (pCWS)

Group	Knee flexion moment (Nm/kg)		Knee extension moment (Nm/kg)		Hip flexion moment (Nm/kg)		Hip extension moment (Nm/kg)	
	CN	TKA	CN	TKA	CN	TKA	CN	TKA
100% pCWS	0.18±0.21	0.19±0.23	0.58±0.13	0.26±0.16	0.77±0.22	0.73±0.22	0.18±0.23	0.35±0.34
130% pCWS	0.24±0.22	0.32±0.29	0.59±0.15	0.31±0.19	0.77±0.22	0.78±0.22	0.16±0.24	0.36±0.41

covered the range of comfortable and high walking speeds of the patients.Joint moments in the sagittal plane and joint powers of the hip, knee and ankle were calculated over the gait cycle. The kinetic variables over the gait cycle of asymptomatic controls were reconstructed to match CWS and 130% CWS for each patient, allowing comparison at equal walking speeds. Principal component analysis was used to detect differences in waveform characteristics between TKA patients and the matching reconstructed data of the asymptomatic controls. Principal component (PC) models were created for each variable of interest. In this study 'Horns' parallel analysis was used to extract PCs of interest, such that only PCs that explained more variance than expected by chance were included. Mixed Model ANOVAs were performed on PC scores of the extracted PCs.

Results: No significant differences were found in anthropometric variables and step length between both groups. The CWS of TKA patients (0.89±0.26 m/s) was significantly lower compared to asymptomatic controls (1.13±0.14 m/s). Three primary modes of variation were found when interpreting the PCs: magnitude operator, a difference operator and a phase shift. Patients showed reduced knee extension moments and increased hip extension moments during late stance compared to asymptomatic controls at both CWS and 130% CWS of the patients, as shown in Fig.1 (group effects on magnitude operators $p<0.05$, discrete peak values shown in Table 1). When walking at high speed, a greater increase in knee flexion moment during loading response was seen in TKA patients compared to asymptomatic controls (Fig.1, interaction effect on difference operator $p<0.05$). Also, increased power generation and absorption peaks over the gait cycle was seen in patients for the knee and ankle joint, while this increase was not shown in the control group (Fig.2, interaction effects on magnitude and difference operators $p<0.05$).



Conclusions: TKA patients walk with a lower CWS, after correcting for speed gait deviations remained. Moreover, deviations remained, or were even amplified when gait speed was increased.TKA patients adapt their walking patterns in a way that yielded a knee extension moment in late stance that was less than half compared to asymptomatic controls. This means that the internal flexion moment by hamstrings and gastrocnemius and consequently the joint contact force (JCF) may be lower. Moreover, early stance knee flexion moment increased when gait speed was increased. Thus lowering the JCF can be a target for these patients. However, this adapted walking pattern also yielded an increase of the hip extension moment (Fig.1). Additionally, TKA patients showed greater increase of their generated and absorbed power when walking speed was increased. Therefore, TKA patients may also adopt a lower CWS to walk mechanically more efficient. Deviations in gait of TKA patients are identified when correcting for speed and when challenging gait speed. While asymptomatic gait is thought of as optimal, future research (energy cost, EMG, modeling to calculate JCF) should investigate whether these TKA gait adaptations may be beneficial.

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JOINT STIFFNESS DURING WALKING IN SEDENTARY YOUNG ADULTS

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Purpose: Young sedentary, obese adults are at a known increased risk for the development of knee osteoarthritis (OA), yet there is a paucity of research investigating gait in these individuals. Existing research has found that there are few differences in typical gait parameters between normal and obese young adults. In older participants, knee joint stiffness has been used to differentiate individuals with knee osteoarthritis from healthy individuals. The purpose of this investigation was to assess whether there were differences in knee joint stiffness between normal and obese sedentary young adults.

Methods: Eighteen (9 normal weight (*N*): 21.9±2.9 years, BMI 21.9±1.4, 24.2±4.8% body fat; and 9 obese (*Ob*): 24.2±3.2, BMI 31.9 ±1.2, 40.8±4.8% body fat) sedentary, otherwise healthy college-aged individuals were recruited to participate in this study. Participants completed a biomechanical gait analysis at both a preferred walking velocity (Ob=1.27 m/s, N=1.26 m/s) and a "fast" walking velocity (1.5 m/s). Ankle, knee and hip joint stiffness were calculated for the weight loading phase of walking from heel-strike to maximum knee flexion. Joint stiffness was calculated as the change in joint angle relative to the change in joint moment. A 2x2 (group x velocity) mixed analysis of variance statistically assessed stiffness at each joint. Cohen's d effect size calculations were also used to assess group differences at each joint for each velocity.

Results: There were no interaction effects between group and velocity at the ankle (p=0.30), knee (p=0.40), or hip (p=0.76). Main effects of velocity at the ankle (p=0.79) and hip (p=0.91) were not significant. At the knee, however, the main effect of velocity showed a statistically significant difference in knee joint stiffness between walking velocities (p=0.019). Knee stiffness was higher at the fast velocity (4.72 Nm/°) compared to preferred walking velocity (4.21 Nm/°). Main effects of group were not significant at the ankle (p=0.46), or hip (p=0.97) yet approached significance at the knee (p=0.06). At the preferred velocity, there were small and moderate effect sizes at the ankle and hip (d=0.46 and d=0.10 respectively), yet there was a large effect size for knee joint stiffness (d=0.88; Ob=5.0 Nm/°, N=3.4 Nm/°). At the fast velocity, there was a small effect size for hip joint stiffness (d=0.17) but large effect sizes for ankle and knee joint stiffness (d=0.84; Ob= 0.98 Nm/°, N=2.54 Nm/° and d=0.96; Ob=5.48 Nm/°, N=3.9 Nm/° respectively).

Conclusions: This initial investigation lends important insight regarding gait in at-risk individuals. Although typical gait parameters were similar between the two groups of sedentary participants, there appear to be differences in stiffness of the lower extremity. While knee stiffness was only trending towards significance, large effect sizes support that a meaningful difference may exist. The obese young adults walked with a stiffer knee, a characteristic of individuals with knee OA. This measure must be further investigated in order to determine its feasibility in identifying individuals at greater risk of developing knee OA.

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LONGITUDINAL CHANGES IN GAIT WAVEFORMS WITH ACL RECONSTRUCTION

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