Bilateral Biomechanical Response to Modifying Peak Vertical Ground Reaction Force with Visual Realtime Gait Biofeedback in Individuals 6-12 Months Post-Anterior Cruciate Ligament Reconstruction

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DISCLOSURES: Elizabeth Bjornsen (N), Alyssa Evans-Pickett (N), Hope Davis-Wilson (N), Amanda Munsch (N), Troy Blackburn (N), Todd Schwartz (N), Jason Franz (Chief Scientific Officer and Cofounder of Vetta Solutions Inc), Brian Pietrosimone (President and Cofounder of Vetta Solutions Inc.)

INTRODUCTION: Aberrant gait biomechanics, a determinant of knee osteoarthritis development, persist years following anterior cruciate ligament reconstruction (ACLR), despite individuals undergoing standard post-operative rehabilitation. Bilateral gait profiles characterized by lesser peak vertical ground reaction force (vGRF) and reduced sagittal (i.e., lesser peak knee extension moments [KEM]) and frontal (i.e., lesser peak knee abduction moments [KAM]) joint moments, and lesser peak knee flexion angles (KFA) have been linked to deleterious biological tibiofemoral cartilage changes and worse symptoms in the first 12-month following unilateral primary ACLR. Preliminary work has demonstrated the potential to modify multiple biomechanical variables critical to knee osteoarthritis development (i.e., KFA and KEM) by cueing a change in peak vGRF in the first 50% of stance but have been limited by small sample sizes and a rigorous study design. A randomized, adequately powered experiment is needed to determine the effect of modifying peak vGRF on critical knee biomechanics to determine the potential for using visual vGRF-driven feedback as a modality for normalizing gait post-ACLR in future clinical studies. Therefore, the purpose of the study is to determine the magnitude of differences in discrete gait biomechanical variables of interest during a standardized treadmill walking protocol across four conditions (three visual feedback conditions and a control condition) and between limbs in individuals 6-12 months post-ACLR.

METHODS: We performed a randomized cross-over experiment in participants 6-12 months following a primary, unilateral ACLR. All participants completed three visual feedback conditions (i.e., decreased, increased, and symmetrical loading) and a control condition that represented their habitual gait without feedback for 3,000 steps on a dual-belt treadmill. The decreased and increased loading conditions cued a bilateral 5% body weight change in the peak vGRF in the first 50% of stance. Symmetrical loading cued the average peak vGRF value of the ACLR and contralateral limb as determined during an initial screening session. The treadmill speed remained constant across all conditions and was set to a self-selected habitual walking speed determined overground. The order of conditions was block randomized and participants were blinded to the condition. All study protocols were approved by the Institutional Review Board and all subjects provided written, informed consent. Biomechanical variables of interest included peak KFA, peak KEM, and peak KAM occurring in the first 50% of stance phase. A mixed effects linear model was constructed to assess within-subject changes between limbs and among conditions separately for each biomechanical outcome of interest. The models simultaneously incorporated the main effects of condition and limb as well as their interaction using an unstructured by compound symmetry covariance matrix and a Kenward-Roger approximation method. Between-group differences by condition and limb were assessed. Model-estimated marginal means and standard errors were calculated, and pairwise comparisons were assessed for variables with a significant overall condition or limb effect. No adjustments for multiple comparisons were performed ($p<0.05$).

RESULTS: Forty-two participants were included in the study (21 ± 3 years of age, 48% female, 8.1 ± 2.0 months post-ACLR; 25 ± 3 kg/m^2). There was an overall condition effect for peak KFA, peak KEM, and peak KAM ($p<0.05$). An overall limb effect was observed only for peak KEM ($p<0.001$). Peak KFA was greater in the increased and decreased loading conditions in comparison to the control condition ($p<0.05$). There was no statistically significant main effect of limb or the condition by limb interaction for peak KFA ($p>0.05$). Peak KEM was greater in the increased loading conditions compared to the control condition ($p<0.01$). An overall condition effect was observed for peak KEM ($p<0.05$), with bilateral peak KEM increases observed in the increased loading condition compared to the control condition ($p<0.05$), but no differences in either limb between the decreased and control conditions ($p>0.05$). Peak KEM was not statistically different between the increased and decreased loading conditions for either limb ($p>0.05$). There was no main effect of limb for peak KAM ($p>0.05$), with minimal changes in peak KAM magnitudes observed across conditions. Notably, the symmetrical loading condition produced similar magnitudes of peak KFA, peak KEM, and peak KAM in comparison to the control condition.

DISCUSSION: The increased loading feedback condition elicited altered sagittal plane kinematics and kinetics (i.e., greater peak KEM and KFA) in comparison to the control condition, similar to peak magnitudes exhibited by uninjured controls. The decreased loading condition produced the greatest peak KFA values across all conditions while maintaining similar peak KEM as compared to the increased loading condition. The symmetrical feedback condition did not produce marked changes in altering gait profiles, nor did KAM change substantially across conditions. Consequently, the increased loading feedback condition acutely cued sagittal plane improvements in the treadmill gait profiles of ACLR patients, similar to gait profiles of uninjured controls.

SIGNIFICANCE/CLINICAL RELEVANCE: Our study identifies vGRF as a promising catalyst for cuing biomechanical changes in peak KEM and KFA, with the increased feedback condition producing generalized improvements in sagittal plane kinematics and kinetics that resemble gait biomechanics of uninjured controls from previous studies. Understanding the magnitude of biomechanical changes exhibited with a 5% cued vGRF increase is useful to develop and assess an extended, visual feedback intervention as a viable method for treating chronic, aberrant gait biomechanics following ACLR.

TABLE 1. Model-Estimated Marginal Means (Standard Error) for Condition by Limb Pairwise Comparisons

	Control (n=41)		Increased (n=39)		Decreased (n=42)		Symmetrical (n=37)	
	ACLR Limb	Contralateral Limb	ACLR Limb	Contralateral Limb	ACLR Limb	Contralateral Limb	ACLR Limb	Contralateral Limb
†Peak KFA	11.614 (1.087)	11.858 (1.121)	14.285 (1.107)	14.872 (1.141)	15.931 (1.078)	16.400 (1.111)	12.190 (1.127)	11.552 (1.162)
†*Peak KEM	-0.019 (0.002)[b,e]	-0.024 (0.002)[b,e]	-0.024 (0.002)[a,e]	-0.030 (0.002)[a,d,e]	-0.021 (0.002)[e]	-0.028 (0.002)[d,e]	-0.020 (0.002)	-0.021 (0.002)[b,c]
†Peak KAM	-0.025 (0.001)	-0.025 (0.001)	-0.024 (0.001)	-0.025 (0.001)	-0.022 (0.001)	-0.024 (0.001)	-0.024 (0.001)	-0.026 (0.001)

†Significant overall effect of condition; *Significant overall effect of limb; [a]Significant difference between Control; [b]Significant difference between Increased Loading; [c]Significant difference between Decreased Loading; [d]Significant difference between Symmetrical Load; [e]Significant difference within group and between contralateral limb; Joint moments were calculated as internal moments, with negative values representing greater extension and abduction for KEM and KAM, respectively.