Real-time Gait Biofeedback Modifies Limb-Level Loading Dynamics After ACL Reconstruction

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BACKGROUND

- Following anterior cruciate ligament reconstruction (ACLR), individuals often experience aberrant gait biomechanics, leading to an increased risk of posttraumatic knee osteoarthritis (PTOA).[1]
- Sustained loading during gait, characterized by smaller 1st and 2nd vertical ground reaction force (vGRF) peaks and greater midstance vGRF, is linked to PTOA onset and progression after ACLR.[2-4]
- Most rehabilitative assessments after ACLR focus on reducing re-injury risk and full return-to-sport, yet few assessments consider long-term joint health such as PTOA-related outcomes.
- Novel real-time gait biofeedback (RTGBF) interventions have been employed to modify aberrant gait biomechanics and normalize knee joint loading after ACLR.[5]

PURPOSE

Primary Purpose: To compare differences in vGRF loading patterns (**Dynamic 1:** difference between 1st peak vGRF and midstance minimum vGRF; **Dynamic 2:** difference between 2nd peak vGRF and midstance minimum) between two RTGBF conditions: i) **High loading:** cueing a 5% body weight (BW) increase in 1st peak vGRF; and ii) **Low Loading:** cueing a 5% BW decrease in 1st peak vGRF (Fig. 1).

Secondary Purpose: To compare differences in 1st peak vGRF, midstance vGRF, and 2nd peak vGRF between High and Low RTGBF loading conditions.

Primary Hypothesis: Dynamic loading (i.e., Dynamic 1 and 2) can be modified through cueing an increase or decrease in 1st peak vGRF. Specifically, we hypothesized that High loading RTGBF will increase Dynamic 1 and Dynamic 2 compared to Low loading.

Secondary Hypothesis: High loading will increase the 1st and 2nd peak and will decrease midstance vGRF compared with Low loading.

METHODS

- We conducted a fully randomized, cross-over design trial which 34 individuals.
- While the participant walked on the treadmill, force plate data were continuously collected for each step on the right and left limb. Using a custom MATLAB algorithm, the average magnitude of the 1st peak vGRF for each of the previous 2 steps on each limb was calculated and displayed as the blue bars on the screen for the participant to see (Figure 2).
- Participants were instructed to match the height of the blue bars relative to the red target line for the High (5% BW increase in 1st peak vGRF) and Low (5% BW decrease in 1st peak vGRF) loading conditions (Figure 2).
- Participants completed 2 RTGBF sessions (High and Low loading) on separate days and walked for 3,000 steps on the treadmill with RTGBF.
- Dependent t-tests were conducted to compare differences in biomechanical outcomes of interest between High and Low loading RTGBF (Table 2).

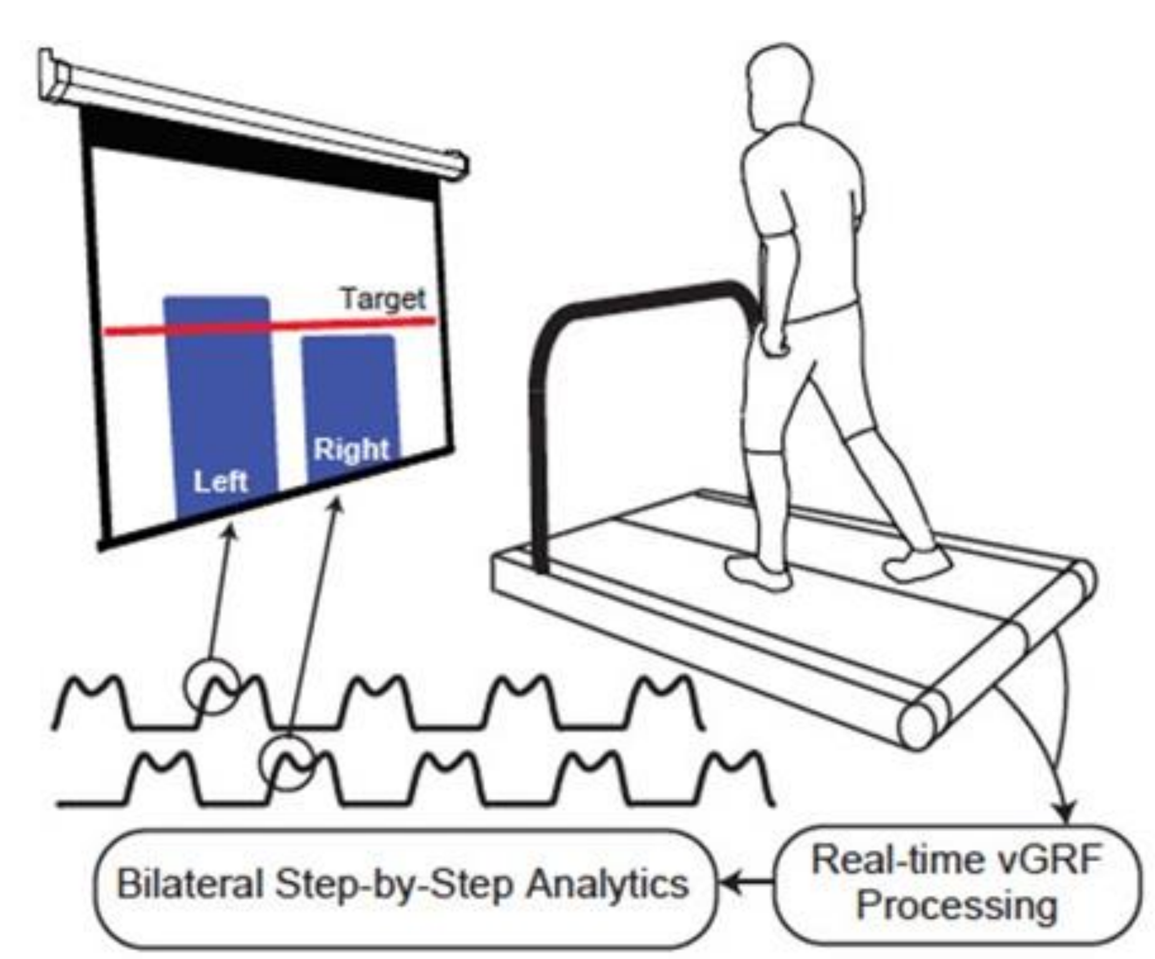

TABLE 1. Participant Demographics	
Age (years)	21.31±.72
Sex (n, %)	
Male	19 (48.72%)
Female	21 (51.28%)
BMI (kg/m²)	24.83±.54
Months Since ACLR	7.97±.31

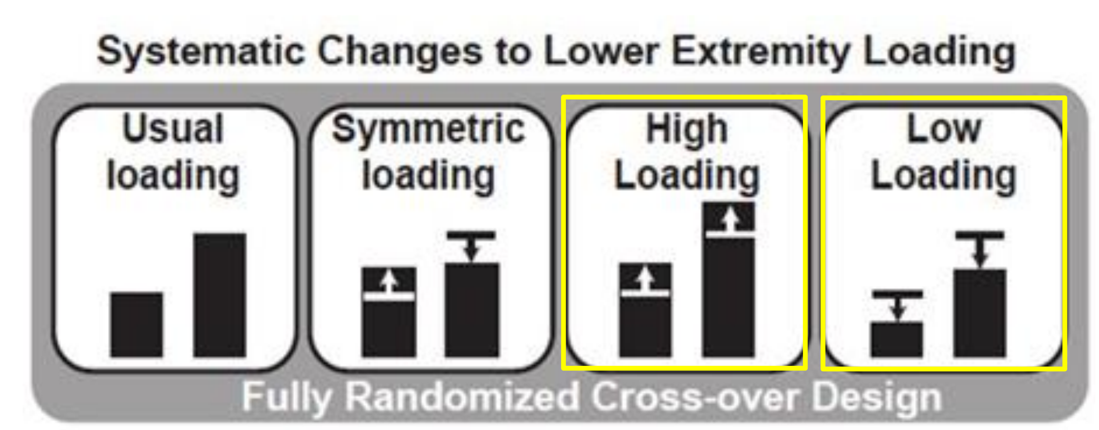

Figure 1. Realtime gait biofeedback (RTGBF) cueing changes in 1st peak vGRF for left and right limbs.

RESULTS

TABLE 2. Mean and standard deviation, and corresponding t-test p-values and Cohen's d effect sizes comparing biomechanical outcomes between High and Low loading RTGBF. *Significant difference (p<0.05) between High and Low loading conditions.

	High	Low	P-Value	Effect Size (95% CI)
vGRF Peak 1	1.19 ± 0.01	1.07 ± 0.05	<0.01*	1.44 (0.99, 1.89)
vGRF Peak 2	1.05 ± 0.06	1.04 ± 0.04	0.193	0.14 (-0.18, 0.46)
Midstance vGRF	0.68 ± 0.07	0.80 ± 0.05	<0.01*	-1.99 (-2.53, -1.44)
Dynamic 1	0.51 ± 0.13	0.27 ± 0.09	<0.01*	1.99 (1.43, 2.53)
Dynamic 2	0.37 ± 0.10	0.24 ± 0.07	<0.01*	1.30 (0.87, 1.73)

DISCUSSION

Cueing changes in 1st peak vGRF using RTGBF results in subsequent dynamic loading changes throughout stance. Cueing an increase 1st peak vGRF promotes a more dynamic loading profile.

- Cueing a 5% BW increase or decrease in 1st peak vGRF caused significant changes in dynamic 1 and dynamic 2.
- 1st peak and midstance vGRF were significantly different when comparing high to low loading.
- Contrary to our hypothesis, 2nd peak vGRF was not significantly different between the High loading and Low loading RTGBF conditions possibly due to participants walking at the same speed during both RTGBF conditions, and 2nd peak vGRF being known to associate with propulsion and walking speed.[6]
- More dynamic loading (i.e., greater vGRF peaks, lower vGRF midstance) may be beneficial in maintaining optimal joint tissue health and mitigating PTOA-related outcomes after ACLR.[5]
- Our data show that a single biomechanical cue (i.e., 1st peak vGRF) has implications on associated biomechanics throughout stance phase and provides a feasible approach to clinically modify key biomechanical patterns.
- Future research should identify whether gait retraining interventions improve short- and long-term knee joint tissue health.

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