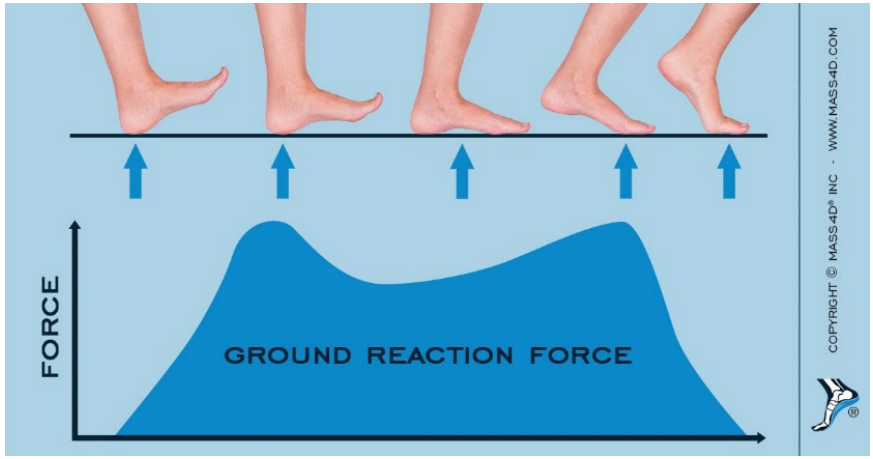
A COMPARISON OF LOADING PATTERNS BETWEEN SHOD AND UNSHOD WALKING IN ACLR INDIVIDUALS

Cassidy Kershner

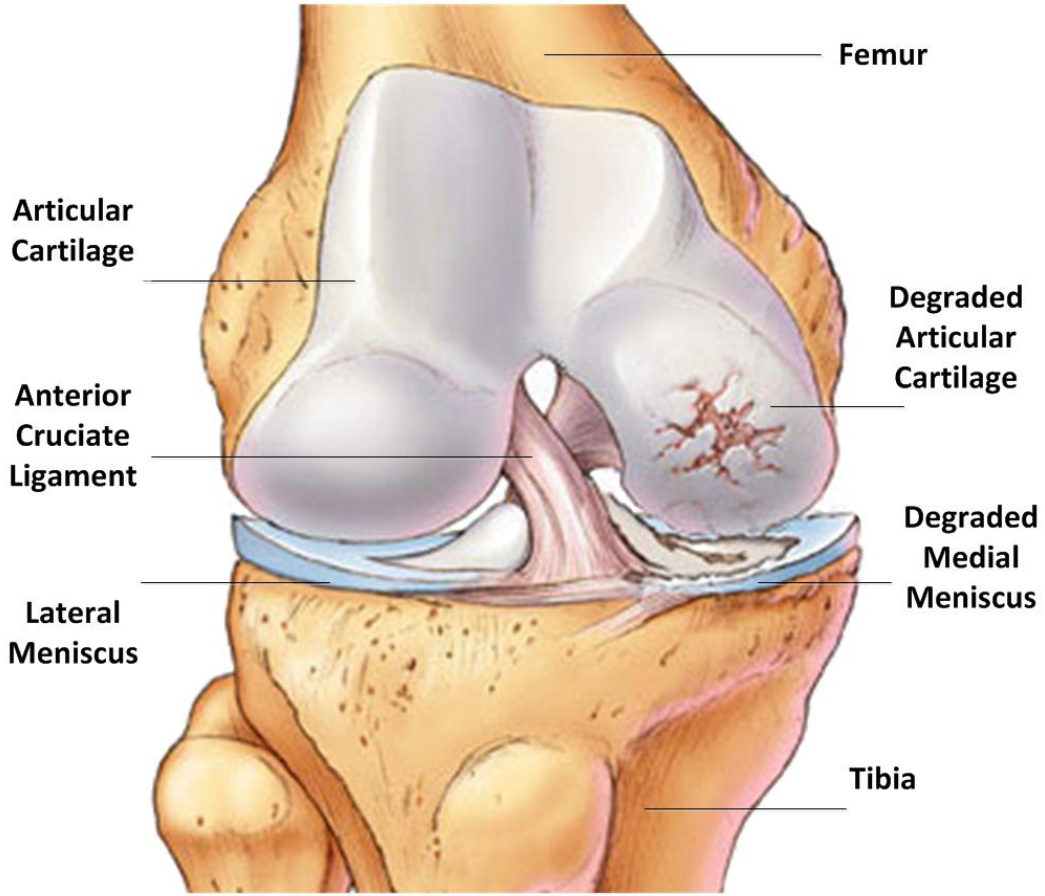
Background

- **Ground Reaction Force (GRF)** is the equal and opposite force that the ground returns to the body during movement.
  - The vertical component (vGRF) is commonly used to characterize gait[2].
- vGRF waveforms during walking differ in **anterior cruciate ligament reconstruction (ACLR)** individuals compared to uninjured controls



(MASS4D, 2017)

Background cont…

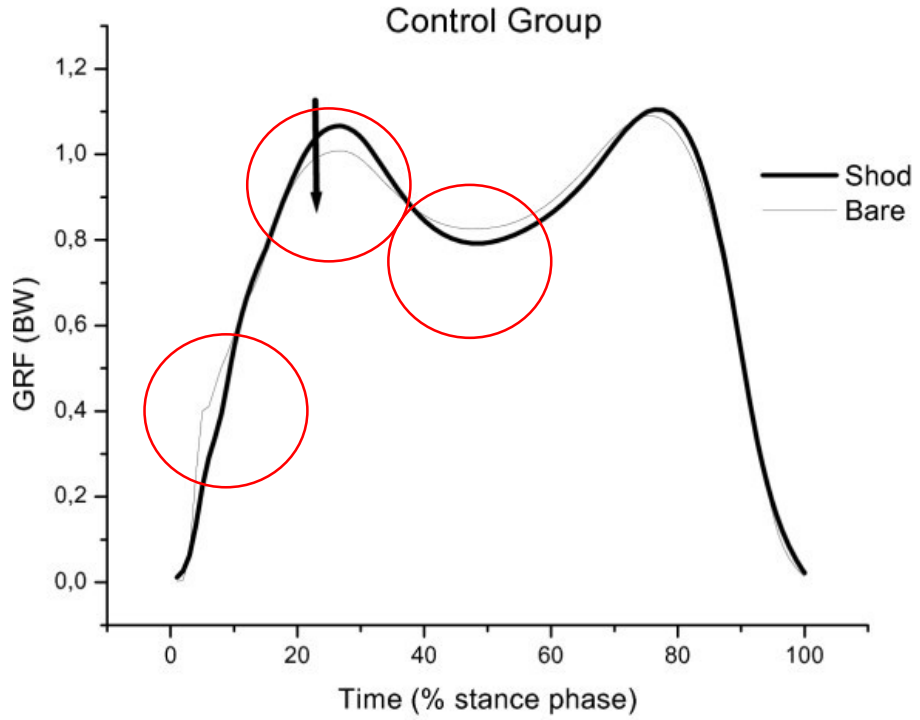


(Umass Orthopedic Bioengineering Research Laboratory, 2021)

ACLR individuals are at higher risk of developing post-traumatic knee osteoarthritis **(PTOA)**[1], which progresses in part due to aberrant changes in walking vGRF patterns following ACLR.[2]

Background cont…

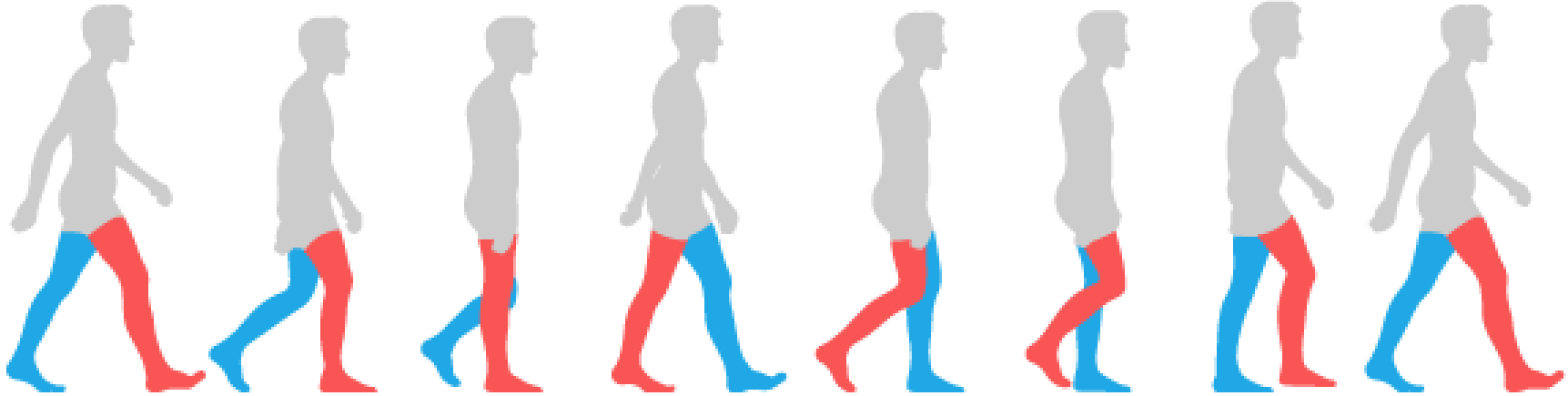
- vGRF is a common variable utilized to characterize gait in ACLR individuals in both **shod (with shoes)** and **unshod** walking **(without shoes)** conditions.
- In uninjured controls, shod walking has been found to elicit:
  - Significant increases in initial peak vGRF. [3,4,5]
  - Significant decreases in midstance vGRF.[4]
- Although they didn't statistically compare differences during early weight acceptance phase, a visual comparison indicates that shod walking has increased vGRF



(Sacco et al., 2010)

Background cont…

It remains unknown how shod and unshod walking vGRF waveforms during gait differ in **ACLR individuals**



(Greene, 2021)

Purpose & Hypothesis

The purpose of this study was to compare vGRF waveforms between shod and unshod walking in ACLR individuals.

We hypothesized that shod walking will elicit larger vGRF in the first and second peaks and smaller vGRF in early weight acceptance phase and midstance as compared to unshod walking

Methods

Procedures:

Table 1. Demographics

N	Sex	Age (years)	BMI (kg/m^2)
29	50% male	21±4	24.1±2.3

- All participants completed 5 shod and 5 unshod error free walking trials at a self-selected walking speed over two staggered and embedded force plates (40 × 60 cm, FP406010, Bertec Corporation, Ohio, USA).
- Stance phase was defined as the period of time from initial contact (vGRF > 20 N) to toe-off (vGRF < 20 N).
- Force data was sampled at 1200 Hz and low-pass filtered at 10 Hz using a 4th order recursive Butterworth filter.

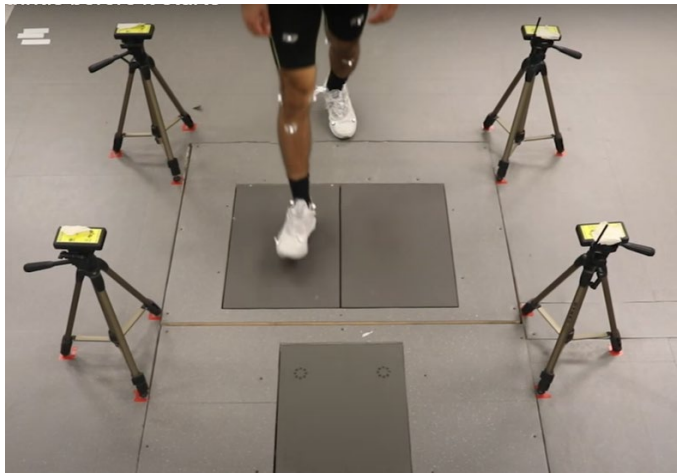
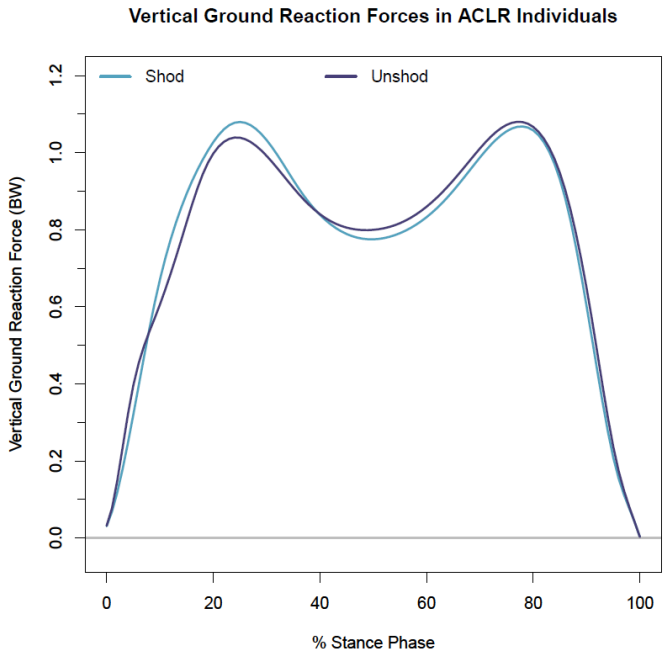


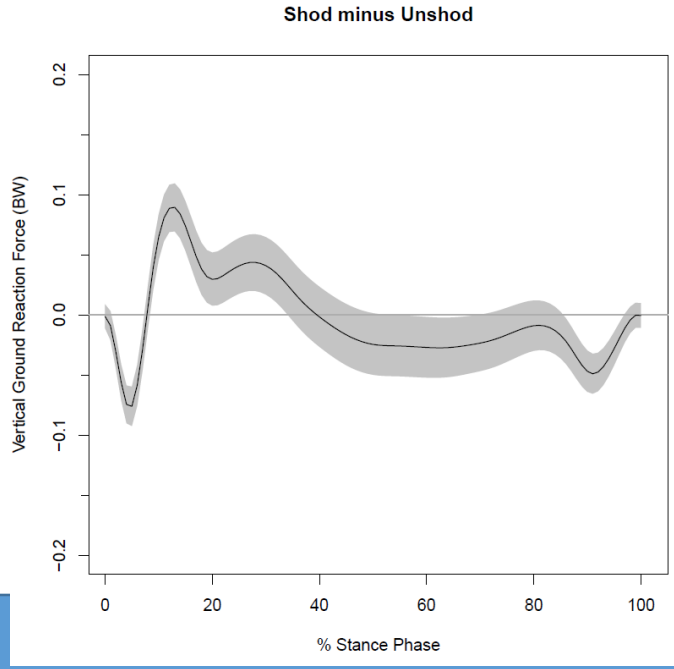
Figure 1. Force plates used to measure vGRF

Methods

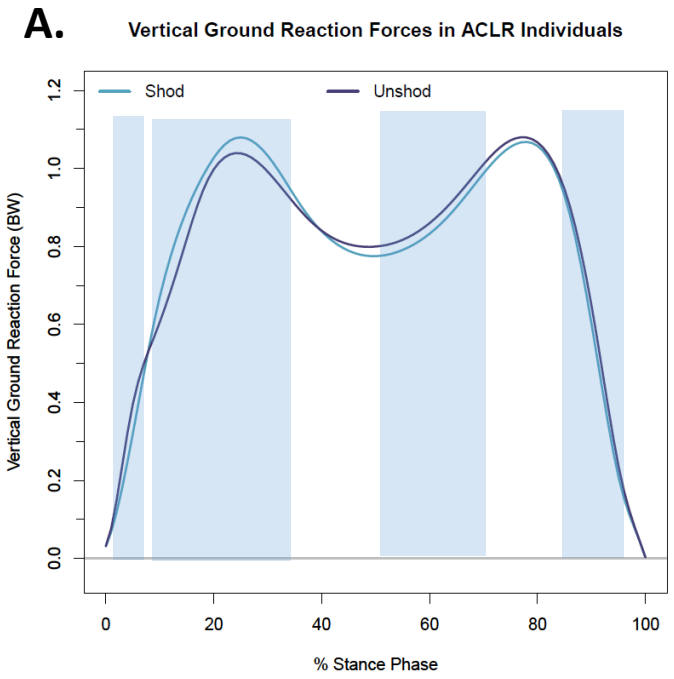
Statistics:

- A **functional waveform analysis of variance** was used to compare differences in vGRF of the injured limb during shod and unshod walking throughout the stance phase of gait in ACLR individuals.
- Time and body-weight normalized ensemble curves were plotted between shod and unshod groups for vGRF
- The conditions were considered different at any percentile of stance phase where the 95% confidence interval, shown by the gray band, for the mean differences between shod and unshod waveforms, shown by the black line, did not cross zero.





Results



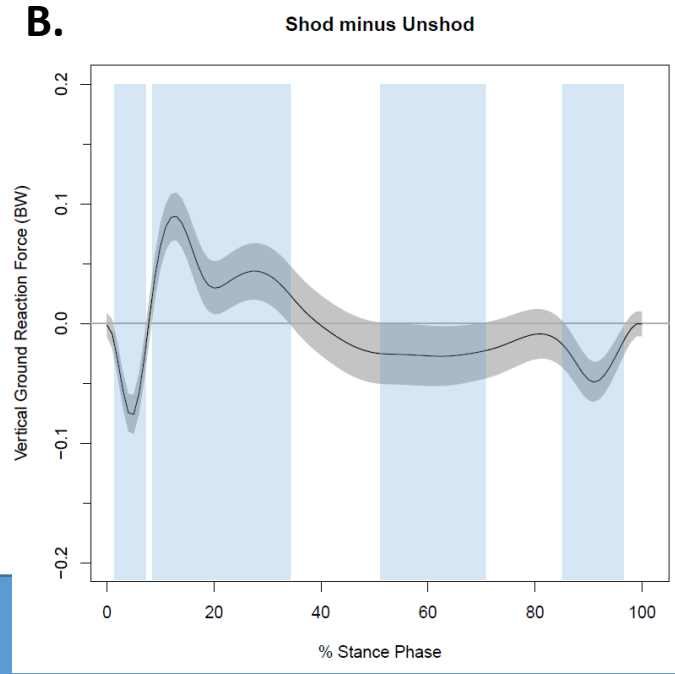


Table 1. Significant vGRF Variation Across Stance

Portions of stance demonstrating mean differences (% stance)	Peak mean difference (%BW)	Location of Mean Difference (% stance)	Effect size (95% CI)
3-8	-7.6	6	-1.5 (-1.7, -1.2)
10-35	8.9	14	1.0 (0.8, 1.2)
55-70	-2.7	63	-0.6 (-0.8, -0.4)
87-97	-4.9	92	-0.8 (-1.0, -0.6)

Figure 2. Comparison of vGRF across stance phase of walking.

Post-Hoc Analysis

Background:

- Peak vGRF is often used to evaluate gait in both shod and unshod conditions.
- Due to the significant differences in vGRF between shod and unshod walking waveforms, we ran a post-hoc analysis to identify a model that predicts first peak vGRF during shod walking.

Statistics

- A ten fold cross validation[6] was used to create a predictive model of first peak vGRF during walking using three predictor variables (peak vGRF during unshod walking, shod walking speed, unshod walking speed).
- Peak vGRFs were calculated from non-time normalized data
- Root mean square error (RMSE) was used to evaluate model accuracy.

Results

vGRF shod = (1.0606* peak vGRF unshod) + (-0.3454 * speed unshod) + (0.3856 * speed shod) + -0.0976

- The RMSE of the final predictive model (Equation 1) was 0.0219 BW

Conclusions

- Our research suggests that differences in vGRF exist between shod and unshod walking throughout stance in ACLR individuals:
    - During weight acceptance
    - During first peak
    - During midstance
    - During push off
- Future research should distinguish shod and unshod conditions when evaluating gait in ACLR individuals for accurate interpretation of walking biomechanics.
- Further analysis is necessary to reduce RMSE in future regression equation predictor models.

Sources

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A COMPARISON OF LOADING PATTERNS BETWEEN SHOD AND UNSHOD WALKING IN ACLR INDIVIDUALS

Cassidy E. Kershner[1], Alyssa Evans-Pickett[1], Brian Pietrosimone[1]

[1] Department of Exercise and Sports Science, University of North Carolina at Chapel Hill

BACKGROUND

- Ground reaction force (GRF) is the equal and opposite force that the ground returns to the body during movement; the vertical component of GRF is often utilized to characterize loading patterns during gait (vGRF).[2]
- vGRF waveforms during walking differ in anterior cruciate ligament reconstruction (ACLR) individuals compared to uninjured controls.[2]
- ACLR individuals are at higher risk of developing post-traumatic knee osteoarthritis (PTOA)[1], which progresses in part due to aberrant changes in walking vGRF patterns following ACLR.[2]
- vGRF is a common variable utilized to characterize gait in ACLR individuals in both shod (with shoes) and unshod walking (without shoes)
- In uninjured controls, shod walking elicits increases in initial peak vGRF[3,4,5], along with decreases in vGRF of midstance.[4]
- It remains unknown how shod and unshod walking vGRF waveforms during gait differs in ACLR individuals.

PURPOSE

Purpose: To compare vGRF waveforms between shod and unshod walking in ACLR individuals.

Hypothesis: Shod walking will elicit larger vGRF in the first and second peaks and smaller vGRF in midstance compared to unshod walking.

METHODS

Procedures:

- Twenty-nine individuals between 6-12 months post unilateral ACLR (50% male ; 21±4 years; 24.1±2.3 kg/m^2 body mass index [BMI]) participated.
- All participants completed 5 shod and 5 unshod error free walking trials at a self-selected walking speed over two staggered and embedded force plates (40 × 60 cm, FP406010, Bertec Corporation, Ohio, USA).
- Stance phase was defined as the period of time from initial contact (vGRF > 20 N) to toe-off (vGRF < 20 N).
- Force data was sampled at 1200 Hz and low-pass filtered at 10 Hz using a 4th order recursive Butterworth.
- Time and body-weight normalized ensemble curves were plotted between shod and unshod conditions for vGRF.

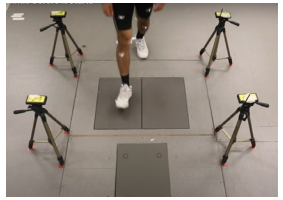

Figure 1. Force Plates used to measure vGRF

METHODS (CONTINUED)

Statistics:

- A functional waveform analysis of variance was used to compare differences in vGRF of the injured limb during shod and unshod walking throughout the stance phase of gait in ACLR individuals.
- The groups were considered different at any percentile of stance phase where the 95% confidence interval, shown by the gray band, for the mean differences did not cross zero, shown by the blue bars (Figure 2).

RESULTS

Results:

- Figure 2.A. displays mean vGRF waveforms across stance for shod (light blue) and unshod (dark blue) walking conditions.
- Figure 2.B. displays mean differences (black line) between shod and unshod walking across stance. The gray band represents the 95% confidence interval.
- Compared to unshod walking, shod walking elicits a larger vGRF between:
  - 10-35% stance during first peak (Table 1).
- Compared to unshod walking, shod walking elicits a smaller vGRF between:
  - 3-8% stance during weight acceptance (Table 1).
  - 55-70% stance during midstance (Table 1)
  - 87-97% stance during push off (Table 1)

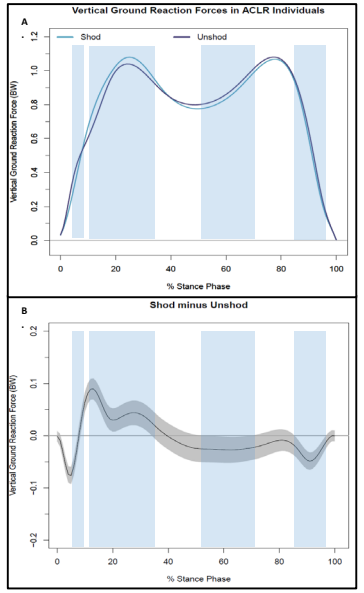

Figure 2. Comparison of vGRF across stance phase of walking.

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1. Pfeiffer SJ, et al. *Medicine and Science in Sports and Exercise*. 2018.
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- Peak vGRFs were calculated from non-time normalized data
- Root mean square error (RMSE) was used to evaluate model accuracy.

Results

vGRF shod = (1.0606* peak vGRF unshod) + (-0.3454 * speed unshod) + (0.3856 * speed shod) + -0.0976

Equation 1. Predictive Model of Shod vGRF from unshod vGRF, unshod speed of walking and shod speed of walking

- The RMSE of the final predictive model (Equation 1) was 0.0219 BW

CONCLUSION

- Our research suggests that differences in vGRF exist between shod and unshod walking during weight acceptance, during first peak, during midstance and during push off phases of stance in ACLR populations.
- Future research should distinguish shod and unshod conditions when evaluating gait in ACLR individuals for accurate interpretation of walking biomechanics.
- Further analysis is necessary to reduce RMSE in future regression equation predictor models.

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