# CONSEQUENCES OF LIMITING ELECTROMYOGRAPHY AND GROUND REACTION FORCES ON MODELLED ANTERIOR CRUCIATE LIGAMENT FORCES

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## Introduction

Modern computational models can accurately quantify anterior cruciate ligament (ACL) loads during dynamic tasks in the laboratory [1,2]. These models use body motion, ground reaction forces (GRF), and electromyograms (EMG). However, acquiring EMG and GRF outside the laboratory, i.e., sports fields or medical clinic, is challenging due to instrument costs, setup time, and skills to acquire and interpret data. Limiting EMG and GRF data, while maintaining model prediction accuracy, would be practically valuable for translation of ACL modelling technology outside the laboratory. We examined the consequences of limiting EMG and GRF on fidelity of model-predicted ACL loads.

## Methods

Twenty-three healthy females (mean (±standard deviation) age, mass, and height of 19.7 (±4.0) years, 59.7 (±9.5) kg, and 1.65 (±0.06) m, respectively) performed a standardized drop-land-jump task, while body motion, GRF, and surface EMG were acquired. Data were used in four neuromuscular models: EMG-informed and static optimization, each with three dimensional (3D) and exclusively vertical GRF. For each model, external biomechanics, lower limb muscle forces, and knee contact forces were computed, and subsequently used to estimate ACL force [1,2]. The ACL force across stance and rank-order of participants based on their peak ACL force were compared across models using one-way repeated measures ANOVA and *post hoc* t-tests via statistical parametric mapping and Kendall's rank correlation, respectively.

## Results

Compared to EMG-informed + 3D GRF, both EMG-informed and static optimization methods using only vertical GRF generated significantly higher ACL force (mean differences, 205.5 N and 253.8 N, respectively) for most of stance. When 3D GRF were used, differences between EMG-informed and static optimization were observed only within the final 20% of stance (mean differences, 116.4 N). Compared with static optimization + 3D GRF, both EMG-informed and static optimization combined with only vertical GRF generated significantly higher ACL force (mean differences, 89.1 N and 137.4 N, respectively) for most of stance (Figure 1). No statistically significant correlations in rank-order of participants were found between EMG-informed + 3D GRF and the other models (Table 1), meaning model configuration affects both absolute and relative magnitude of ACL forces. Although, vertical GRF is readily measured in-field using commercially available instruments, this study demonstrated using only vertical GRF substantially overestimated ACL loads. Simplifying the neural model to static optimization overestimated ACL loading even when modelling used 3D GRF.

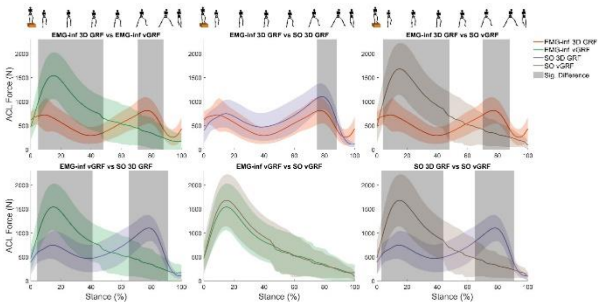


*Figure 1: Pairwise comparisons of ACL force (±1 standard deviation) over stance of drop-land-jump estimated via four modelling approaches. vGRF, vertical GRF; EMG-inf, EMG-informed; SO, static optimization*

| | SO + vGRF | SO + 3D GRF | EMG-inf + vGRF |
|---|---|---|---|
| Correlation | -0.028 | -0.012 | 0.067 |
| p-value | 0.876 | 0.958 | 0.676 |

*Table 1: Kendall's rank correlation of peak ACL force between different modelling approaches during drop-land-jumping.*

## Discussion

Simplifying requirement for experimental measures of muscle activation patterns via static optimization and/or reducing GRF from 3D to only vertical force resulted in spurious model estimates of ACL loading. Compared to modelling with 3D GRF, using only vertical GRF resulted in much larger ACL forces due to a lack of a posteriorly directed GRF during landing. The consequence of neglecting EMG in favour of static optimization was more complex. Individual responses were highly variable, but resulted in a small but significant increase in ACL loading for the cohort studied. Finally, rank order of participants based on their peak ACL loading could not be preserved under any simplified modelling approach used in this study. Findings indicate both EMG and 3D GRF should be included to model ACL loading during dynamic tasks.

## References

1. Nasseri A et al. Comput Meth Program Biomed 184, 2020.
2. Nasseri A et al. Med Sci Sports Exerc 53(6), 2021