Does Shear Force Contribute to Knee Extensor Moment Deficits During Double Limb Squats Following ACLr?

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Summary

Individuals 2-6 months post-ACL reconstruction reduce surgical limb knee extensor moment (KEM) during double-limb squats using measurable adjustments in force distribution, direction and center of pressure in the absence of large kinematic alterations.

Introduction

Following anterior cruciate ligament reconstruction (ACLr) individuals adopt strategies to reduce KEM in the surgical (Sx) limb. During double limb squats, large KEM deficits are present in the absence of observable between limb difference in sagittal plane joint angles [1]. Along with a shift in vertical ground reaction force (vGRF) away from the Sx limb, a more anterior position in center of pressure (COP) position was found to explain 70% of the variance in KEM deficit [2]. A more recent study found minor adjustments in pelvic rotation [3] also relate to reduced KEM, suggesting that adjustments in anterior/posterior (ap) shear force may also contribute to reduced KEM in the Sx limb. Therefore, this study aims to determine if individuals post-ACLr exhibit between limb differences in apGRF and if apGRF difference add to the prediction of KEM deficits during a double limb squat.

Methods

Forty individuals (27.0±10.3 years; 24 females; 1.71±0.07 m; 70.0±10.8 kg) 2-6 months (113.5±22.6 days) post-ACLr performed double-limb squats at comfortable speed and depth. 3D kinematics and GRF were collected. KEM (inverse dynamics), COP position, vGRF and apGRF for each limb were calculated at peak knee flexion.

To characterize the direction and magnitude of apGRFs, the angle of the 2D resultant GRF vector from vertical was calculated (θ, Figure 1A). A negative number indicates a vector directed posterior. COP position was determined relative to the longitudinal axis of the foot using markers place on second toe and middle of the heel counter of the shoe (Figure 1B). Position was normalized to foot length. A larger COP% indicates farther from the heel. Between-limb difference in GRF angle (Diff-θ) and COP% (Diff-COP%) were calculated as Sx - non-surgical (NSx) limb. To characterize between-limb loading deficits, limb symmetry indices (LSI) were calculated for KEM and vGRF (Sx/NSx). Paired t-tests compared variables between limbs. A forward linear regression was performed to determine the predictive value of apGRFs (Diff-θ) on LSI-KEM after considering for LSI-vGRF, Diff-COP%.

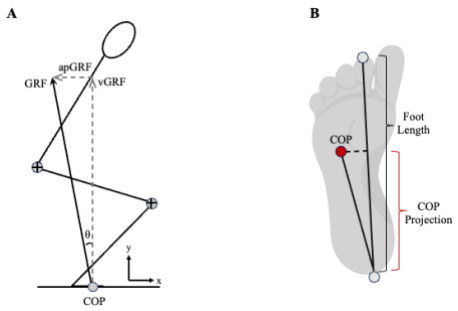

Figure 1: **A**: Ground reaction force (GRF) vector and angle (θ). **B**: Center of pressure (COP) position and its projection on the foot.

Results and Discussion

When compared to the NSx limb, individuals exhibited significantly smaller KEM and vGRF in the Sx limb (Table 1). LSI-KEM (0.56 ± 0.23) and LSI-vGRF 0.83 ± 0.13) indicated 44% and 17% deficits, respectively. On average, COP position was 7.47±8.07% more anterior and apGRF angle was directed more anterior 2.78±2.39 degrees in the Sx limb (Table 1). LSI-vGRF and Diff-COP% together, explained 74% of variance in LSI-KEM (LSI-vGRF 56.5%). Diff-θ explained an additional 6% of the variance in LSI-KEM (R^2 = 0.80). Smaller vGRF, more anterior COP position and more anteriorly directed apGRF was related to greater KEM deficit in the Sx limb.

Conclusions

Previous work describes compensation strategies to reduce Sx limb KEMs including reducing weight bearing force and an anterior shift in COP. The addition of apGRF improved the prediction model. In the absence of observable asymmetries in joint angles and posture, these adjustments in force distribution, direction and COP reflect subtle strategies to reduce KEM demands.

References

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Table 1: Moment, vertical GRF, COP position and GRF angle between surgical and non-surgical limb: mean(standard deviation). *p<0.001

	Surgical	Non-surgical	Mean Difference	95% Confidence Interval		Effect Size
				Lower	Upper	
KEM (Nm/kg)	0.54(0.22)	1.00(0.34)	-0.47(0.32)*	-0.57	-0.36	-1.45
vGRF (N)	378.77(96.69)	461.04(102.29)	-82.27(73.04)*	-105.63	-58.91	-1.13
COP%	54.70(10.39)	47.22(9.80)	7.47(8.07)*	4.89	10.05	0.93
apGRF Angle (θ, degrees)	1.20(1.62)	-1.58(1.12)	2.78(2.39)*	2.02	3.55	1.17