How Does the Anterior Cruciate Ligament Affect Center of Pressure in the Knee?

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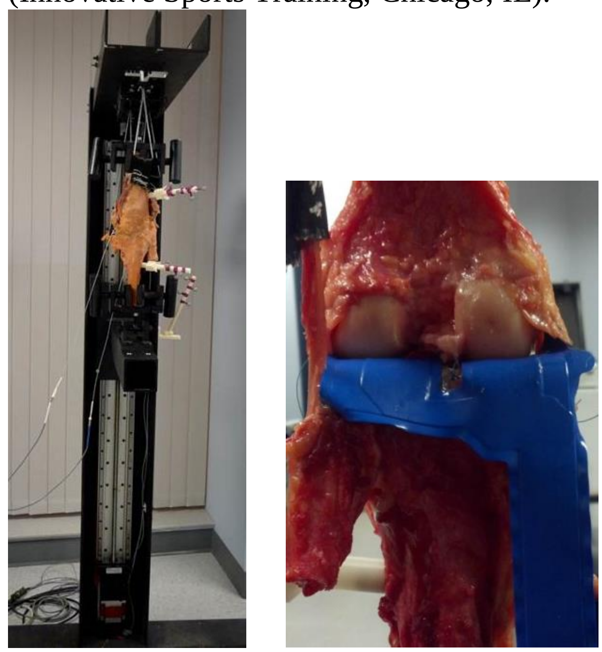
INTRODUCTION

Anterior cruciate ligament (ACL) injuries are one of the most debilitating lower extremity injuries that occur in both athletes and general population. ACL tears often cause knee instability, which lead to secondary injuries like meniscus tears, occult fractures, and the early development of knee osteoarthritis (OA)[1,2]. Because OA development is caused, in part, by the long-term changes in dynamic joint loading[3], it is important to understand the changes in dynamic joint loading that occur after ACL injury. Center of pressure (COP), the point where the resultant of all forces act upon, may identify how loading patterns, along with increased loads contribute to the changes in dynamic joint loading that leads to OA.

Contact pressure has been measured in vitro to validate computational models[4], examine the tibio-femoral pressure patterns[5], and investigate pressure changes after simulated meniscus tears[6]. Furthermore, in vivo assessments have identified contact points during movement[7], and predicted pressure and COP in validated computational models[8,9]. However, the effects of ACL deficiency on the center of pressure in the knee have not been thoroughly investigated.

METHODS

Six intact cadaver knee specimens (5 left, 1 right, 3 male, 3 female, mean age 73 ± 5) were fixed into a custom-built device capable of automatically flexing and extending the knee at various speeds (Figure 1a). The knees were flexed and extended at a speed of 1.5 in/s. Novel (Novel, Munich, Germany) pliance knee pressure sensors were inserted between the tibia and femur from the posterior aspect of the knee and sutured in place (Figure 1b). The sensors measured joint contact forces over the medial and lateral tibiofemoral compartments as well as the overall COP across both tibiofemoral compartments. Joint contact forces and center of pressure were measured before and after the ACL was sectioned. The kinematics of the tibia and femur were simultaneously tracked using a six camera Motion Analysis Eagle System (Motion Analysis Corporation, Santa Rosa, CA), and flexion/extension angles were calculated using The Motion Monitor (Innovative Sports Training, Chicago, IL).



(a) (b)

Figure 1. a) knee positioning and loading device and b) posterior view of the knee with sensor inserted.

The trajectory of the COP was exported from the Novel pliance software and plotted for all three specimens. The range of motion and excursion of the COP trajectory were calculated in x- and y-directions. The COP excursion was calculated in the x- and y- directions for one cycle of knee flexion-extension by normalizing each COP curve to the same number of data points (880) and summing the absolute values of the difference from point to point in x- and y-directions. The range of motion was the maximum and minimum values of the COP in x- and y-. The ratio of the excursions of the ACL deficient (ACLD) knee to the knee with the ACL were calculated.

RESULTS AND DISCUSSION

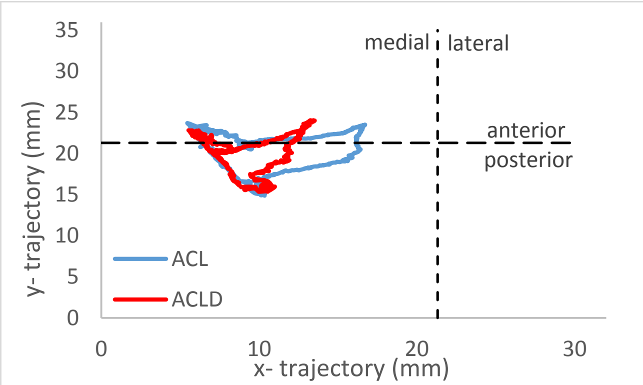


Figure 2: COP curves a representative specimen for ACL and ACLD knees for one specimen.

The COP trajectory was plotted during a cycle of knee flexion/extension. The x- and y- ranges as well as the overall area covered by the COP trajectory was smaller when the ACL was cut (Figure 2). This combined with the fact that in 5 specimens the x- and y- range of the COP decreased (Table 1) suggests that the loads applied to the knee were concentrated to a smaller part of the knee. This may lead to wear and deterioration within concentrated areas of the joint surfaces and contribute to the development of post-traumatic OA.

The COP excursion of the x- and y- coordinates between intact and ACL deficient knees increased in both coordinates for four specimens. Only one specimen had a decrease in COP excursion. Increased COP excursion is a sign of instability in the spine and ankle[10,11], suggesting the COP excursion is another indicator of knee instability after ACL tear.

One of the limitations to this study is that due to the configuration of the Novel sensor, the muscles could not be loaded when the sensor was in place, as it caused sensor buckling. In future studies, different sensors should be used in order to determine how the COP is affected when tendons are loaded.

CONCLUSIONS

Decreased COP range and increased COP excursion were identified within the tibiofemoral joint following ACL sectioning. These findings may indicate changes in stability and loading of the knee are present when the ACL is comprised.

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Table 1. Excursion (total length) and Range (absolute max-absolute) of the Center of Pressure Trajectory (mm) in X- and Y- with ACL and without the ACL (ACLD).

	ACL Excursion		ACLD Excursion		Ratio of ACLD/ACL Excursion		ACL range		ACLD range		Ratio ACLD/ACL Range	
Specimen	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1	67.58	52.68	67.58	61.45	0.94	1.17	9.59	7.52	12.92	9.74	1.35	1.3
2	79.61	91.22	88.63	103.48	1.11	1.13	11.28	8.84	8.02	8.71	0.71	0.98
3	78.83	56.13	94.72	86.09	1.2	1.53	9.56	8.24	7.62	7.97	0.80	0.97
4	67.46	64.19	94.48	74.08	1.4	1.15	9.4	5.67	6.55	3.15	0.70	0.55
5	149.15	118.96	202.87	136.5	1.36	1.15	9.41	10.24	10.07	7.99	1.07	0.78
6	68.16	60.11	52.85	58.6	0.78	0.97	10.73	11.48	2.85	8.75	0.27	0.76
MEAN	**85.13**	**73.88**	**100.19**	**86.70**	**1.13**	**1.18**	**10.00**	**8.67**	**8.01**	**7.72**	**0.82**	**0.89**