Assessing rehabilitation progress following ACL reconstruction surgery

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I. Introduction

Rupture of the anterior cruciate ligament (ACL) is a common lower limb injury, with approximately $250,000$ instances occurring annually in the United States [1]. Almost $100,000$ of these patients undergo ACL reconstruction (ACLR) surgery each year, which is accompanied by a rehabilitation program lasting several months [2]. To assess recovery, clinicians look for abnormal movement patterns and asymmetries in range of motion, strength, power, and control while the patient performs a series of dynamic tasks [3]. However, since these assessments are not cost-effective for large groups or frequent sessions [4], they cannot be performed regularly throughout the course of a rehabilitation program.

Automating these assessments by quantifying biomechanics during commonly used rehabilitation tasks can increase patient access to rehabilitative care. One such exercise, the leg press, is frequently used for developing lower-limb power, with the goal of improving athletic performance and safety [5]. This work describes camera, force, and encoder data collected from 16 ACLR patients performing a unilateral leg press exercise on 10 occasions throughout the rehabilitation period. We present preliminary power results for the patients and discuss our future analysis of the video data to quantify lower-limb joint angles and loading.

II. Experiment and Methods

Sixteen ACLR patients (3 female and 13 male, ages 17-48, average height 1.79 ± 0.0798 m, average body mass 78.6 ± 13.3 kg) were recruited for this study. The subjects were at least 4 months out of surgery. One control subject was matched with each ACLR subject for height, weight, sex, and age.

The ACLR subjects completed the leg press test 10 times over the course of the study, with at least one week in between tests. Control subjects completed the test once. During each testing session, the subject performed four 35-second leg press intervals (single-leg, two intervals on each). These intervals consisted of 30% and 50% of the subject's body weight on each leg, in randomized order. Subjects were instructed to complete as many repetitions of the leg press motion as possible, reaching a 90-degree knee angle on each cycle.

Each test was performed on a leg press machine (Body Masters MD-122) instrumented with a force plate (Loadstar Sensors, DI-1000) and encoder (US Digital H6-10000) at University of Michigan's MedSport Facility in Ann Arbor, Michigan. Additionally, two stereo cameras (ZED Stereolabs) synchronously collecting video were mounted on a wall near the leg press 4 meters away.

Patient power was computed for each test using the load cell and encoder data, then normalized by patient-specific parameters.

III. Preliminary Results and Discussion

The normalized peak power during the 50% body weight test, averaged across 16 subjects, is shown for 10 test weeks in Fig. 1(b). In each test instance, the healthy leg outperforms the ACLR leg, and the mean peak power in healthy and ACLR legs improves by 75.8% and 76.1% respectively. Although both legs show similar percent increase in power over the rehabilitation period, asymmetry between the healthy and surgery side remains.

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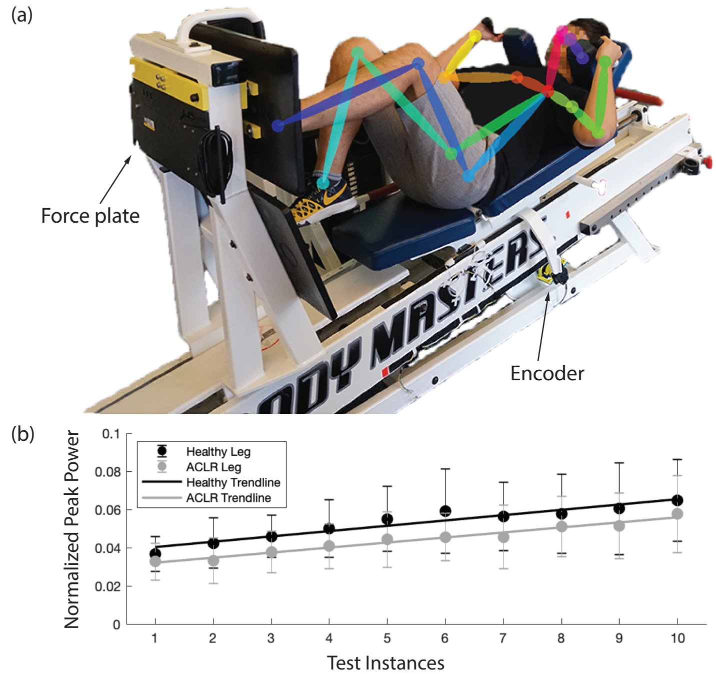

Fig. 1: (a) Leg press test setup with an overlay of a subject's 2D pose estimation. Videos were recorded on wall-mounted stereo cameras (not pictured). (b) Mean and standard deviation of normalized peak power across 16 subjects over 10 test instances for the 50% body weight test.

Our previous work used 2D pose estimation (shown in Fig. 1(a)), developed by [6], to re-create the force and encoder data using video observations alone [7]. In future work, we plan to utilize 3D pose estimation algorithms to estimate joint angles and loads. By extending this work to recover joint-specific data, we hope to highlight the effectiveness of tracking rehabilitation progress in ACLR patients using a markerless, inexpensive camera-based method.

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