Burnett School of Medicine at TCU: SPT Final Thesis

Energy Absorption Contribution and Return to Sport Scale After Primary Anterior Cruciate Ligament Reconstruction in Young Adult Athletes

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Abstract

Research Question: 1) Do young athletes who returned to preinjury sport following primary anterior cruciate ligament reconstruction differ in the biomechanical loading distribution of energy across their lower extremity joints at the time of release from physical therapy compared to athletes who did not return to sport? 2) Can the ACL-Return to Sport Index (ACL-RSI) be used to predict a young athlete's ability to return to pre-injury sport following primary anterior cruciate ligament (ACL) reconstruction?

Background: ACL reconstruction is a common injury in young athletes competing in sports that involve cutting and pivoting. This injury can pose significant physical and psychological barriers to return to sport. The objective of this study is to determine the impact of biomechanics and psychological factors on the ability to return to pre-injury sport following primary anterior cruciate ligament (ACL) reconstruction in young athletes.

Methods: A cohort of 39 athletes aged 13 - 25 who underwent primary ACL reconstruction with the intention of returning to preinjury sport. Biomechanics were evaluated with a jump-landing task and isokinetic quadriceps strength testing at the time of release from physical therapy to determine energy absorption contribution of the lower extremity joints. Psychological factors were evaluated using the ACL-return to sport index (ACL-RSI) at the time of release from physical therapy. Participants were followed up with at least 12 months after release from physical therapy and asked whether they returned to preinjury sport.

Results: Of the 39 participants, 28 returned to preinjury sport (RTS) and 11 did not (NRTS). There was a significant difference in peak ground reaction force between the groups in both the involved and uninvolved limbs ($p=0.04$). The involved hip in the RTS group had a significantly greater energy absorption contribution (EAC) ($p=0.03$). The NRTS group had a significantly higher EAC in both the involved ($p=0.04$) and uninvolved ($p=0.03$) ankles. There was no significant difference in the RSI score between the groups ($p = 0.41$).

Conclusions: Participants who returned to preinjury sport demonstrated altered biomechanical energy absorption compared to those who did not return to sport. ACL-RSI at the time of release from physical therapy may not be fully predictive of an athlete's ability to return to sport at 1-year post-assessment.

Research Question

1. Do young athletes who returned to preinjury sport following primary anterior cruciate ligament reconstruction differ in the biomechanical loading distribution of energy across their lower extremity joints at the time of release from physical therapy compared to athletes who did not return to sport?
    a. Hypothesis: We hypothesize that athletes who did not return to sport would have less energy absorption in their involved knee compared to those who returned to sport. The thinking behind this theory is that we predict athletes who did not return to sport will attempt to "protect" their surgical knee by altering their biomechanics to absorb more energy through other lower extremity joints, such as the ankle and hip.

2. Can the ACL-Return to Sport Index (ACL-RSI) be used to predict a young athlete's ability to return to pre-injury sport following primary anterior cruciate ligament (ACL) reconstruction?
    a. Hypothesis: We hypothesize that athletes who returned to preinjury sport following ACL reconstruction will have had a higher ACL-RSI score (greater psychological readiness) at the time of release from physical therapy.

Introduction

The anterior cruciate ligament (ACL) is a key ligament for knee stabilization and rotational motion. It provides the connection between the femur and tibia and is commonly injured in high impact athletics that involve twisting motions and quick changes in direction, such as soccer and basketball. It has been estimated that 1 in every 3000 people tear their ACL in the United States each year[1] and it continues to increase, as more young adults participate in competitive sports at earlier ages. The most common treatment for an ACL tear is an ACL reconstruction, an arthroscopic-assisted surgery that includes removal of the torn damaged tissue and reconstruction with a graft. Patellar tendons, quadriceps and hamstrings are the most common grafts utilized. With an average rehabilitation time of 9 months, ACL reconstructions pose a significant barrier to return to preinjury sport. This timeline is particularly important to consider in the adolescent population, as these patients are commonly working to return for their upcoming competitive sports seasons or to secure college athletic scholarships.

There are often changes in movement patterns following ACL reconstruction as the athlete becomes accustomed to their reconstructed knee. Studying joint loading and muscle strength are used in post-operative physical therapy as means to quantitatively gauge rehabilitation progress and estimate future joint performance. Alterations in joint loading and movement patterns in the surgical limb puts the athlete at risk for re-injury to the surgical limb, in addition to injury to the contralateral limb.[2] Energy absorption contribution (EAC) is used to estimate lower extremity muscle activity during landing exercises.[4,5,6] The aim of this study was to compare EAC of the lower extremities in athletes who returned to preinjury sport versus those who do not. We hypothesized that athletes who did not return to sport would have deficits in the EAC of the involved limb, particularly of the involved knee.

Successful return to sport following ACL reconstruction requires not only physical recovery, but also psychological recovery, as fear and lack of confidence in the involved knee can have an effect of joint biomechanics as well. Patients have high expectations when it comes to returning to sport post-operatively, especially in young adults with aspirations to continue their sport at a collegiate level. Feucht et al showed that 91% of patients expected to return to sport following ACL reconstruction.[7] While many athletes are physically recovered at the time of release from physical therapy, fear and lack of confidence in the reconstructed limb can hinder return to sport. While there are several questionnaires that can be used to evaluate psychological readiness to return to sport, the ACL-RSI is the only one specific to psychological readiness following ACL reconstruction.[3] The ACL-RSI consists of 12 questions written to evaluate emotional response, confidence, and risk appraisal following ACL reconstruction. The purpose of evaluating ACL-RSI scores in our study was to determine whether the ACL-RSI score at the time of release from physical therapy could be used to predict an athlete's ability to return to pre-injury sport at least 1-year post-assessment. We hypothesized that participants who did not return to sport would have lower ACL-RSI scores.

Methods

Of note, many of the procedures, participation criteria, and biomechanical protocols are identical to the standard evaluation used at the Texas Health Sports Medicine Biomechanics Laboratory.[6,8]

Participants

A total of 39 athletes (20 male and 19 female) who were involved in a level 1 sport (e.g., basketball, football, or soccer) at the time of injury were enrolled in this study (Table 1). Participants were considered eligible for the study if they were between the ages of 13 – 25 and received either a patellar bone-tendon-bone or hamstring autografts, had a first-time ACL injury, had an intention to return to pre-injury level sport, completed physical therapy, and have none of the following concomitant injuries: : full-thickness chondral defect of ≥ $1cm^2$, grade II or III medial collateral ligament or lateral collateral ligament sprain, posterior cruciate ligament tear (grade III), or simultaneous fracture with an ACL tear.

Before participation in the study, all participants signed an informed consent; participants aged ≤ 17 years provided parental permission and child assent. The institutional review board of Texas Health Resources approved all research procedures.

Procedures

A retrospective study design was used. All testing was completed at Texas Health Sports Medicine Biomechanics Laboratory. At the time of return to sport (RTS) time point, participants completed biomechanical analysis on a jump-landing task, isokinetic quadriceps strength test, and anterior cruciate ligament return to sport scale (ACL-RSI).

Participants who completed the RTS assessment between February 2017 and December 2019 were called via telephone at least one year after completion of RTS assessment. They were asked whether they were able to return to the same level of sport after their ACL reconstruction as they participated in prior to their injury.

Table 1. Participant Demographics[a]

	Return to Sport (n = 28; male = 13; female = 15)	Not Return to Sport (n = 11; male = 7; female = 4)	*P*-Value
Age, y	15.6 ± 1.5	16.1 ± 1.0	0.38
Height, cm	171.8 ± 8.8	173.5 ± 12.8	0.65
Mass, kg	69.8 ± 13.9	80.5 ± 19.3	0.06

[a]Values are presented as mean ± SD.

Jump-landing task

The jump-landing task methods were taken from the standard protocols described in Malafronte et al[8] and A 10-three-dimensional camera Motion Capture System with a sampling rate of 120 Hz was used to capture joint motions in all three planes during the jump-landing. Thirty-three reflective markers were adhered to each participant's skin/clothing with double sided tape.[6,9,10] Retroreflective markers were attached to the spinous processes of the seventh cervical vertebra, twelfth thoracic vertebra, between the fourth and fifth lumbar vertebra, sternum, bilateral acromion process, anterior superior iliac spine, posterior superior iliac spine, greater trochanter, anterior thigh, medial and lateral malleoli, calcaneus, and first and fifth metatarsal heads. Three additional retroreflective markers were attached in the sacrum as a cluster. Two ATMI force plates capturing at 1200 Hz (Advanced Mechanical Technology, Inc, Watertown, MA) were used to obtain joint kinetics to allow accurate time sequencing during data collection and data processing.

Each participant completed three trials of a jump landing task.[11,12,13] Each trial began with the participant standing on top of a 30cm-high box that was placed at a distance of 50% of their height from the force plate. Participants were instructed to jump forward by pushing the box with their feet at the same time and land on the force plates followed by immediate vertical jump for maximal height.[14] Trials were repeated if participants jumped vertically from the box, did not reach the force plate, or did not perform the task in a fluid motion.

Isokinetic Quadriceps Strength Test

The methods we used for Isokinetic Quadriceps Strength Testing is taken from the standard protocol described by Goto et al.[15] Prior to the strength testing, each participant's mass was assessed and used later to normalize the collected strength data. Isokinetic QUADS was assessed at 60°/sec, using the Biodex Multi-Joint System (Biodex Medical Systems Inc., Shirley, NY). Participants were seated on the Biodex system and secured with padded straps around the distal end of shank, thigh, pelvis, and torso to minimize accessory and compensatory movements during the testing[16,17]. The femoral condyle of the testing limb was aligned with the Biodex axis of rotation following the manufacturer's instructions. Following the familiarizing session consisting of up to 2-5 repetitions of submaximal knee extension/flexion, participants were instructed to extend and flex their knees as hard and as quickly as possible for 5 consecutive times. The order of testing was the non-surgical limb followed by the surgical limb.

ACL-RSI

Patients completed the ACL-RSI scale when they were cleared from physical therapy. The ACL-RSI consists of 12 questions where patients grade their answers on a Likert scale of 0-

100 with higher scores indicating better psychological readiness to return to sport after ACL reconstruction. It includes 3 domains: emotion, confidence, and risk appraisal.

Data Processing and Reduction

Data was collected from the bilateral limbs. Kinematics and force data was transported into Visual 3D software (C-motion, Inc. Germantown, MD) for data processing and reduction. Markers and ground-reaction force data were filtered using fourth-order Butterworth filter with a cutoff frequency of 12Hz. Peak vertical ground reaction force (vGRF) was calculated and normalized to participants' body mass ($N\ kg^{-1}$). Energy absorptions of the hip, knee, and ankle were calculated by integrating the negative area of the power curve during the jump-landing task and normalized to the height and weight (J Ht*Wt). Energy absorption contribution (EAC) for hip, knee, and ankle was calculated relative to total EA (sum of hip, knee, and ankle EA) and express as a percentage.[6,8] All biomechanical variables were calculated during the loading phase of a jump-landing task, defined as the period from the initial foot contact (≥10N) to the maximal knee flexion angle, and averaged across 3 trials.

Peak QUADS values (N·m) were averaged across five trials and then the average was normalized to body mass in kilogram ($N{\cdot}m\ Kg^{-1}$). Finally, the sum of 12 items of the RSI score was normalized and expressed as percentage.

Data Analysis

Participants were dichotomized into two groups based on whether they returned to the same level of sport at least one year after the return to sport assessment. Separate independent-t tests were used to assess the differences in descriptive variables between groups. Mann-Whitney U test was performed for the variable that had non-equal variance.

Results

There were 28 participants in the return to sport (RTS) group, meaning they confirmed via telephone that they were able to return to their prior level of sport after their ACL reconstruction. There were 11 participants in the group that did not return to their prior level of sport (NRTS). Table 1 displays the characteristics between the groups. There were no significant differences in age (*P* = 0.38), height (*P* = 0.65) or mass (*P* = 0.06) between the groups. There was not a significant difference between the groups with regards to the number of days between surgery and when participants received a phone call asking if they were able to return to sport (RTS: 1480.9 ± 326.1 days; NRTS: 1567.7 ± 311.5 days; *P* = 0.38).

There was a significant difference in peak ground reaction force between the groups in both the involved (RTS: 2.54 ± 0.74; NRTS: 1.86 ± 0.62; *P* = 0.01) and uninvolved (RTS: 3.14 ± 0.58; NRTS: 2.69 ± 0.53; *P* = 0.04) leg. (Table 3).

For the Energy Absorption Contribution (EAC) during the first 50 milliseconds, the data is reported related to the surgical limb (involved) and non-surgical limb (uninvolved). The involved hip in the RTS group had greater EAC compared to the involved hip in the NRTS group (*P* = 0.03). There were no significant differences in the EAC at the involved (*P* = 0.54) or uninvolved (*P* = 0.21) knee. However, in the ankle, the NRTS group had a higher EAC in both in involved (*P* = 0.04) and uninvolved (*P* = 0.03) limb (See Table 2 and Figure 1).

There was no significant difference in the groups regarding RSI score at the time of RTS (P = 0.41). (See Table 4 and Figure 2).

Table 2. Energy Absorption Contribution[a]

	RTS (n = 28)	NRTS (n = 11)	*P* Value
Hip			
Involved	41.37 ± 33.0	21.22 ± 20.41	0.03[b]
Uninvolved	24.60 ± 20.58	27.10 ± 20.78	0.21
Knee			
Involved	27.06 ± 27.80	33.12 ± 25.75	0.54
Uninvolved	42.59 ± 33.24	27.29 ± 33.43	0.21
Ankle			
Involved	31.57 ± 20.22	45.66 ± 12.63	0.04[b]
Uninvolved	30.19 ± 19.37	45.61 ± 18.60	0.03[b]

[a]Values are presented as mean ± SD.
[b]$p < .05$.

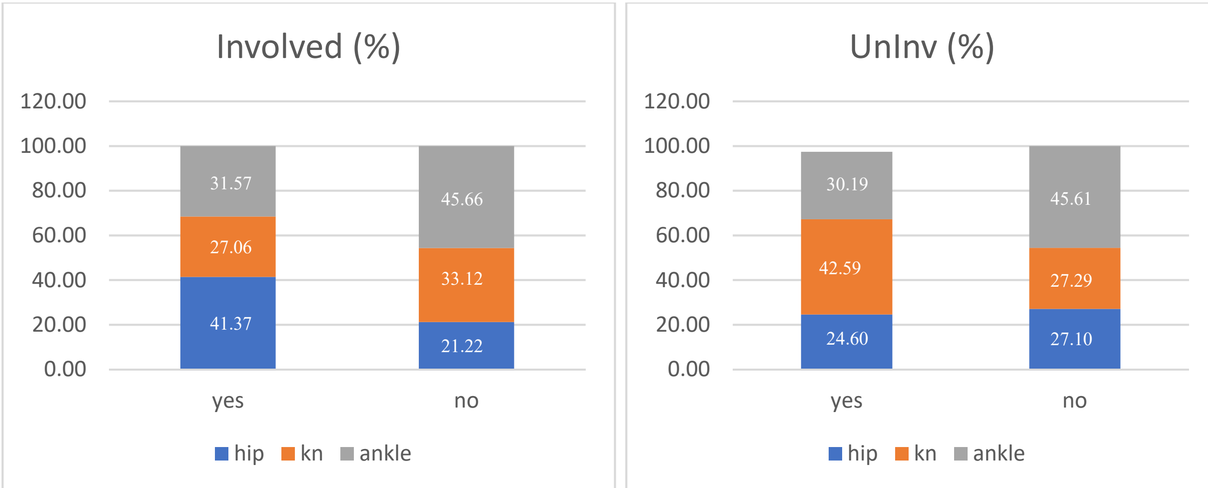

Fig. 1. Involved and Uninvolved limb energy absorption contribution (EAC).
Abbreviations: yes, return to sport; no, did not return to sport.

Table 3. Peak Vertical Ground Reaction Force[a]

	RTS (n = 28)	NRTS (n = 11)	*P* Value
Involved leg	2.54 ± 0.75	1.86 ± 0.62	0.01[b]
Uninvolved leg	3.14 ± 0.59	2.69 ± 0.53	0.04[b]

[a]Values are presented as mean ± SD.
[b]$P < .05$.

Table 4. ACL - RSI[a]

	RTS (n = 28)	NRTS (n = 11)	*P* Value
RSI	81.76 ± 13.32	79.75 ± 12.87	0.41

[a]Values are presented as mean ± SD.

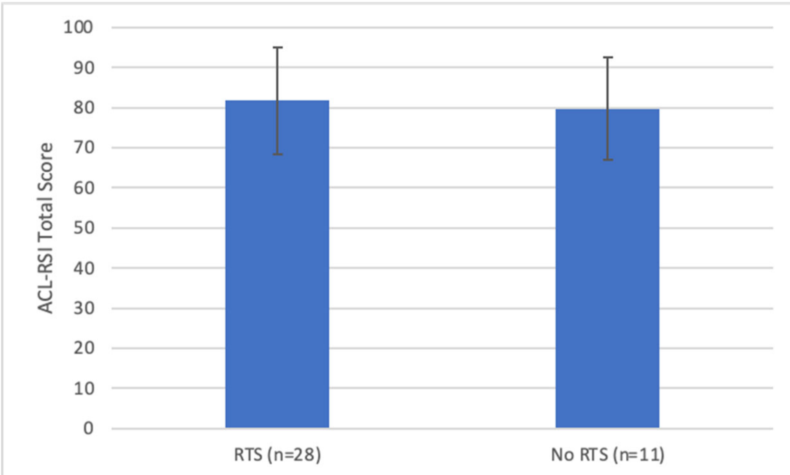

Figure 2. Total ACL-RSI scale in participants

Abbreviations: RTS, return to sport; No RTS, did not return to sport.

Discussion

Biomechanics

We found that the EAC of the involved hip (41.37 ± 33.0) in the RTS group was significantly greater (p=0.03) than the EAC of the involved hip (22.2 ± 20.41) in the NRTS group. The mechanism behind the increased EAC in the involved hip in the RTS group is not completely understood but is similar to the findings of a 2018 paper by Garrison et al. In this study, EAC was investigated in patients three months post-op from ACL reconstruction and compared the results to healthy controls. It was found that the involved hip had a greater EAC compared to healthy controls.[6] The mechanism of increased hip EAC in the involved limb is a point that should be looked into further in future studies. We also found that the NRTS group had a significantly higher EAC in both the involved and uninvolved ankle when compared to the ankle EAC in those who RTS. While the mechanism of this is also unknown, we predict the athlete is incorrectly overcompensating their movement on the jump landing test to decrease the amount of force received through their knee.

ACL-RSI

Athletes who returned to preinjury sport had a greater ACL-RSI score (81.76 ± 13.32) than athletes who did not return to preinjury sport (79.75 ± 12.87). While this finding was not statistically significant (p = 0.41), it can be used to illustrate that psychological factors following ACL reconstruction do have an influence on return to sport. Importantly, the ACL-RSI should likely not be used as the sole means of predicting how successful an athlete will be at returning to pre-injury sport. These findings are unique because to our knowledge, there is not another study that focuses specifically on psychological factors impacting adolescent athletes following ACL reconstruction. Our sample size (n=39) was a weakness of our study. Investigating the impact of ACL-RSI scale on return to sport in a larger data pool could yield significant results and provide further insight into the specific psychological factors that impact adolescents. Further directions could also look the different psychological factors that differ in adults vs. adolescents following ACL reconstruction.

Future Directions

Future studies could investigate this research question on a larger scale. The results of our study are reflective of 39 participants but performing a similar analysis with more patients would give greater insight into the predictive capacity of EAC and ACL-RSI on return to sport. In addition, future studies could investigate the results of the RSI survey further to see whether those who did not return to sport were consistently lacking in any of the three domains tested on the RSI. In addition, comparing the RSI results in adults versus adolescents following ACL reconstruction could help identify whether age impacts psychological readiness. Future studies should also work to identify the mechanism behind increased hip EAC on the involved limb in athletes who returned to sport. In addition to the mechanism behind increased EAC the ankles of those who did not return to sport.

Conclusions

Participants who are at least 1-year post-RTS assessment who were able to return to preinjury sport following primary ACL reconstruction demonstrate different biomechanical energy absorption during jump landing test compared to patients who could not return to sport. In addition, the ACL-RSI assessment score may not be entirely predictive of an athlete's ability to return to sport at least 1 year post assessment and should be used in conjunction with other methods of analysis.

Compliance

This study was approved by the Institutional Review Board of Texas Health Resources. Before participation in the study, all participants signed an informed consent; participants aged ≤ 17 years provided parental permission and child assent. There are no financial disclosures or conflicts of interest to declare.

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