Lower medial hamstring activity after ACL reconstruction during running: a cross-sectional study

Einar Einarsson, Athol Thomson, Bart Sas, CLint Hansen, Magnus Gislason, Rodney Whiteley

ABSTRACT

Objective Anterior cruciate ligament reconstruction (ACLR) predisposes footballers for subsequent ACL and hamstring (HS) injury. This case series examines HS muscle activation patterns during the running in ACLR patients (bone-patellar tendon-bone (BTB) and (HS) graft) after completion of functional criteria allowing return to training.

Methods Electromyography (EMG) recorded from medial and lateral HS bilaterally during treadmill running (12, 14 and 16 km/hour) from 21 male ACLR patients on average 7 months from surgery (5-9) that underwent (HS) (n=12) or BTB reconstruction (n=9) were compared with 19 healthy runners. Main outcome measures: EMG signal was normalised to peak during the running. Pairwise comparisons were made for each muscle group examining stance and swing activation for mean and peak EMG for each patient group and leg.

Results Significantly lower relative peak activation in stance (not swing) phase for medial HS was seen for all conditions with effect sizes ranging from −0.63 (controls, BTB non-injured leg) to −1.09 (HS injured). For lateral HS only BTB injured were significantly lower in stance phase (−1.05).

Conclusion ACLR patients show neuromuscular alterations during different phases of running. The finding of reduced medial HS activity in stance phase might have implications for knee instability and HS muscle injury on resumption of sport.

INTRODUCTION

After anterior cruciate ligament reconstruction (ACLR) returning to sport at the same level and minimising risk of reinjury is complex. Eighty-three per cent of elite athletes return to sport, and at 3 years post-ACLR, only 65% of professional football players are still playing at same level. ACLR failure rates are documented to be between 2.8%–5% in international cohorts, and in athletes 5%–17%. Previous ACLR is a predisposing factor for subsequent ACL reinjury, and hamstring (HS) injury in athletes. Debate remains over which surgical procedure for ACLR is superior in terms of functional and other outcomes despite a large body of research from high level studies. Commonly ACLR is performed using either autologous bone-patellar tendon bone (BTB) or HS grafts.

The medial HS is a synergist for the ACL providing a restraining force to anterior translation and lateral rotation of the tibia. The lateral HS can off-load the ACL as antagonists to medial rotation of the tibia. Previous work suggests that HS muscle activation during the jumping and the Nordic HS exercise may not normalise for up to 6 years after ACLR and that restoration of HS muscular activation can be influenced by graft type (HS graft or a BTB graft). Limited information exists regarding motor patterns of ACLR subjects during running but we have described different HS activation patterns between prefoot and postfoot contact in a healthy population under different loading conditions. HS muscle injuries appear most likely to happen at the late swing phase of running, yet are plausible during stance phase. A role of the HS is to act as agonists for the anterior cruciate ligament but mechanism of activation in these phases after ACLR during the running is unclear. Therefore, we aim to compare HS activation in HS and BTB ACLR patients during treadmill running who have cleared return to sport criteria and, compare these findings to healthy athletes.
METHODS

This study examined summation of electrical potentials created by depolarisation of sarcolemma (muscle fibre excitation) by means of wireless surface electromyography (EMG) signals (hereafter termed ‘muscle activation’) of the medial and lateral HS of both legs during different treadmill running speeds for a cohort of ACLR subjects (‘patient’) and a comparison cohort of active healthy male adults (‘comparison’).

Patient group

Twenty-one male participants who underwent an isolated ACLR either with either BTB or HS graft were included in the study. All patients participated in pivoting sports and were all at level 9 or 10 on the Tegner scale. The athletes had completed all clinical criteria (<10% deficit on Isokinetic and functional field testing, pain-free, no swelling on swipe test and full ROM allowing resumption of high speed running. The patient group included patients that underwent an HS (n=12, age 26±3.84 years, weight 74.16±7.19 kg and height 176.89±5.6 cm) and BTB reconstruction (n=9, age 27±7.69 years, weight 80.40±9.44 kg, and height: 178.49±7.29 cm) and were 5–9 months, postsurgery.

Comparison group

Nineteen injury-free male runners (age 35.4±7.8 years, weight 77.6±8.4 kg, height 179.1±5.6 cm).

Informed consent was obtained for each volunteer participant.

Muscle activation (EMG) from two muscles on both legs Semitendinosus (‘medial HS’) and Biceps Femoris (‘lateral HS’) were recorded at 2000 Hz using a Delsys Trigno Wireless System (Boston, Massachusetts, USA), with electrodes placed following the seniomyography.org guidelines. The EMG signal was filtered using a fourth-order band-pass filter, with low pass cut at 30 Hz using Matlab

Each step was extracted and normalised from foot contact to foot contact leading to 100 separate time points (1%–100%). It is reported that HSs show two activation peaks during running, one in late swing, one during the stance. Instead of considering only a single peak of activation across the entire gait cycle, more information can be gathered by considering these peaks independently. Specifically, the late swing peak appears implicated in high-speed running HS injury. Conversely, non-contact ACL injury can only happen during stance. Accordingly we sought to document both these peaks on either side of foot contact and did so by splitting our data from running trials into ‘swing’ and ‘stance’ phases.

HS activation levels show increased amplitude as well as increased variability with increasing speed. To better represent running loads likely encountered during normal training, we examined three treadmill running speed trials (12, 14, and 16 km/hour) which reflect moderately fast running likely encountered during higher volume running the athletes would perform during their training. Athletes ran at the selected trial speed until they felt their gait was ‘normal’ and then 30 s of data collection was commenced. The running speeds were presented in random order. Data from all of these strides (maximum 30) for each subject, for each leg, were individually averaged for subsequent analysis. The peak EMG value as well as the integrated EMG (iEMG) ie, area under the curve in swing and stance phases was identified for each running trial, for each subject. The signal was then normalised to its respective highest value obtained during all the running trials for the individual subject.

To describe the comparison between swing and stance phases for the medial and lateral HS muscles the activation across all three speeds (12, 14 and 16 km/hour) were pooled to reflect ‘typical’ activation during moderate to high intensity running training likely encountered in football (figure 1).

Data processing and statistical analysis

Peak and mean EMG intra-group differences were identified (left vs right leg, injured vs uninjured leg) for activation in swing and stance phases of the multimuscle EMG series using paired Hotelling’s T2 statistics. The significance level was set to p<0.05.

An analysis of variance was conducted considering muscle groups, running phase, subject leg, peak EMG, average EMG (iEMG) and patient categories. Subsequent pairwise comparisons with post hoc correction were made for each muscle group examining prefoot and postfoot contact phases for both iEMG and peak EMG for each patient group and leg.

RESULTS

For the comparison cohort, no significant differences were found comparing left and right legs so data for both legs were pooled for further analyses. For the
patient cohort, data are presented for both their operated (‘injured’) and uninjured legs. These analyses are summarised for the HS muscle pairs in table 1. Across all participants and conditions, stance phase occurred from 50% (by definition) to an average of 79.4%±2.9% of the gait cycle.

When comparing the activation during swing and stance phases for the lateral HS, significantly lower iEMG (effect sizes (ES): −1.99 to −3.62) values were seen in all groups but only peak EMG (ES: −1.05) for the stance phase for BTB graft leg, while all other peak EMG conditions showed no significant differences between swing and stance activation. By contrast significantly lower relative iEMG activation in the swing phase for the medial HS was seen for all conditions with iEMG ES ranging from −3.08 to −3.84. For peak activation significantly lower activation was seen in all conditions except for HS non-injured with ES ranging from −0.63 to −1.09, and the lowest effect in controls and highest in HS graft.

For the medial HS all patient groups showed similar peak activation in swing phase (BTB injured: 0.82, BTB healthy: 0.80, HS injured: 0.81, HS healthy: 0.81) while comparisons are slightly higher (0.85). All groups show a reduction in medial HS peak activation comparing swing to stance phase (Comparisons: 0.73, BTB injured: 0.60, BTB healthy: 0.58, HS injured: 0.56, HS healthy: 0.68). Figure 1 shows a more consistent peak activation of the lateral HS in swing (comparisons: 0.84, BTB healthy: 0.82, HS injured: 0.77, HS healthy: 0.77) and stance (comparisons: 0.83, BTB healthy: 0.74, HS injured: 0.79, HS healthy: 0.79) with the exception of BTB injured leg where the lateral HS had significantly higher activation in swing (0.87) than stance (0.73) with an associated ES of −1.05. It is also worth noting that there is a bigger difference in iEMG from swing to stance in medial HS activation than in the lateral HS with ES largest in controls at −3.84 with the lowest of the BTB-injured (ES of −1.99, table 1).

**DISCUSSION**

Despite reaching functional clinical goals allowing return to field-specific training after ACLR, we report the novel finding of reductions in medial HS activity during stance phase running.

ACLR athletes have higher risk of HS injury,11,12 and the data presented here should be of interest in running field sports which also have a high burden from ACL injury (eg, Soccer, Rugby, Gaelic Football, etc). Previous research shows repeated sprinting impairs both strength and neuromuscular activation of the lateral HS.36,37 We suggest that the alterations in activation post-ACLR found here shed light on the documented association between ACLR and higher risk of HS injury.11,12

HS ACLR had both the lowest activation during stance phase and the largest reduction in activation from swing phase to stance phase, with the next largest reduction in the BTB injured group. We speculate that the altered peak medial HS activity in stance phase might be a factor in knee stability potentially leading to laxity4,36 or ACL reinjury.36

Differences in neuromuscular strategies during the running after ACLR could be related to loss of sensory
input from the ACL graft, therefore, preservation of remnant ligament might improve neuromuscular function, but with no drop in activation during swing phase we speculate that the reduction in activation may begin early postoperative as result of antalgic reduction of activation in donor site HS (during stance phase). Conceivably this learnt behaviour persists during rehabilitation, long after pain has resolved. Patients examined in this study had reached functional return to sport criteria, however, varied in time taken (3–9 months). The present study is not powered to examine effect of time after surgery, however, muscle activation differences have been reported 1–2 years post-ACL reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. Br J Sports Med 2018;52:128–38.


Hansen C, Einarson E, Thomson A, et al. Peak medial and (not lateral) hamstring activity is significantly lower during stance phase
of running. An EMG investigation using a reduced gravity treadmill. 


