Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture

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ABSTRACT

Background The decision as to whether or not an athlete is ready to return to sport (RTS) after ACL reconstruction is difficult as the commonly used RTS criteria have not been validated.

Purpose To evaluate whether a set of objective discharge criteria, including muscle strength and functional tests, are associated with risk of ACL graft rupture after RTS.

Materials and methods 158 male professional athletes who underwent an ACL reconstruction and returned to their previous professional level of sport were included. Before players returned to sport they underwent a battery of discharge tests (isokinetic strength testing at 60°, 180° and 300°/s, a running t-test, single hop, triple hop and triple crossover hop tests). Athletes were monitored for ACL re-ruptures once they returned to sport (median follow-up 646 days, range 1–2060).

Results Of the 158 athletes, 26 (16.5%) sustained an ACL graft rupture an average of 105 days after RTS. Two factors were associated with increased risk of ACL graft rupture: (1) not meeting all six of the discharge criteria before returning to team training (HR 4.1, 95% CI 1.9 to 9.2, p≤0.001); and (2) decreased hamstring to quadriceps ratio of the involved leg at 60°/s (HR 10.6 per 10% difference, 95% CI 10.2 to 11, p=0.005).

Conclusions Athletes who did not meet the discharge criteria before returning to professional sport had a four times greater risk of sustaining an ACL graft rupture compared with those who met all six RTS criteria. In addition, hamstring to quadriceps strength ratio deficits were associated with an increased risk of an ACL graft rupture.

INTRODUCTION

After ACL reconstruction (ACLR) the typical goal is to return to sport (RTS) as quickly as possible, preferably performing at the same level as pre-injury yet protected from re-rupture. To increase the chances of successful and safe RTS, specific criteria have been developed.

Many RTS criteria have been suggested, some based on the time from ACLR as the only criterion for RTS,1 others advocating combining time with subjective and objective criteria.¹ The most commonly described tests are isokinetic strength tests, functional tests, clinical assessment and related subjective questionnaires.³ ⁴ Ardern et al⁵ reported that, after an ACLR, 81% of patients return to any kind of sport, 65% return to their pre-injury level of sports participation and only 55% return to competitive sports. Also, after RTS the risk of re-injury (graft rupture) ranges from 6% to 25%⁶–¹³ whereas the risk of contralateral ACL injury ranges from 2% to 20.5%.¹³

Given the high incidence of re-ruptures of reconstructed ACLs, it is striking that among the studies examining potential risk factors for ACL re-injury, the main focus has been on non-modifiable factors like gender, age, activity level and anatomical characteristics.⁷ ¹⁴–²¹ In the only prospective study that addressed neuromuscular control and coordination, poor neuromuscular control was a risk factor for ACL graft rupture.²² Among 281 cases of ACLR, younger athletes had a higher chance of graft rupture than older athletes.²³ A 10-year difference in age was associated with a 2.6 times greater chance of ACL graft rupture. Among 1820 patients after primary ACLR, younger athletes had a higher activity level and a higher incidence of ACL re-injury.²⁴ There was no gender difference in the rate of ACL graft ruptures.²⁵ Compliance with rehabilitation programmes is substantially lower among younger athletes, which might also contribute to the higher ACL re-injury risk.²⁶ Based on data from the Swedish National Knee Ligament Register, the combination of being young and playing football is a substantial risk factor for revision surgery.²⁷ ²⁸

Quadriceps and hamstring strength contribute to a successful RTS.²⁹ However, it is unknown whether strength is a risk factor for an ACL graft rupture. In addition, other factors like poor knee alignment or poor neuromuscular control are often described as predisposing factors for ACL re-injuries,³⁰ ³¹ ³² ³³ ³⁴ ³⁵ ³⁶ ³⁷ ³⁸ ³⁹ ⁴⁰ ⁴¹ ⁴² but only one study has reported data. In a study of 56 athletes by Paterno et al, transverse plane net moment impulse at the hip, dynamic frontal plane knee range of motion, side to side differences in sagittal plane, knee moment at initial contact and deficits in postural stability were associated with a three times greater risk of ACL graft rupture.¹⁴

The purpose of this study is to evaluate whether strength or functional tests, which are frequently used as RTS criteria, are risk factors for an ACL graft rupture in a group of male professional athletes.

MATERIALS AND METHODS

Approval was obtained from the Ethics Committee of the Anti-Doping Lab Qatar Institutional Review Board (IRB application number EX2013000006) and waiver of informed consent was received.

Study design and participants

In this study we included only male professional athletes registered with sports clubs in Qatar.
All athletes were treated at Aspetar Orthopedic and Sports Medicine Hospital (Aspetar) with primary ACLR between 1 January 2008 and 21 September 2015. All players returned to normal team training, which is how we define RTS. International athletes and athletes who could not be followed up because they left the country were excluded. Of the 377 athletes identified as having been treated for an ACL injury during this period, 158 met our inclusion criteria (figure 1).

Aspetar employs medical staff (clinicians, physiotherapists, nurses) in the National Sports Medicine Program (NSMP), which provides medical and sports science services to all sport clubs in Qatar. As part of this programme, injured athletes are obliged to visit Aspetar for any injury. Consequently, all injuries are recorded in their hospital medical record. We were therefore able to capture all ACL graft ruptures occurring after RTS during the period from 1 January 2008 to 21 September 2015. By the end of this follow-up period all athletes included in this study had RTS for at least 6 months after completion of their rehabilitation, unless a graft rupture occurred, in which case this was the endpoint of follow-up. The average follow-up for athletes who suffered an ACL graft rupture after RTS was 105 days (range 1–874 days), whereas for those who had no graft rupture the average follow up was 731 days (range 182–2060 days).

Five surgeons were involved using two different surgical techniques: hamstring or bone–patellar tendon–bone (BPTB) grafts. Both techniques were standardised and a femoral tunnel via an anteromedial portal was used for all ACLRs.

Immediately after surgery, athletes who had only ACLR were advised to weight bear as tolerated and no brace was used. If, in addition, a meniscus repair was also done, a brace limiting knee movement was used. If, in addition, a meniscus repair was also done, a brace limiting knee range of motion from 0° to 90° was used for 4 weeks and the athletes were advised to weight bear as tolerated.

All athletes completed a rehabilitation programme at Aspetar, supervised by a specialised team of sports physiotherapists who only treat ACL-injured patients.

Rehabilitation was divided into three phases: (1) early; (2) intermediate; and (3) advanced. In the early phase the focus was on controlling swelling, restoration of range of motion and activation of the quadriceps and hamstring muscles. In the intermediate phase the focus was on optimisation of muscle strength, proprioception and neuromuscular control. Towards the end of this phase a running progression programme also took place. Finally, in the advanced phase, rehabilitation was sports-specific with athletes starting to perform various sports- and position-specific drills. At the end of this phase an assessment was conducted before allowing participation in normal team training.21 Our RTS criteria were criteria-based, not time-based.

Athletes who met all six discharge criteria (table 1) and were discharged clinically by their treating orthopaedic surgeons were recorded as ‘fully discharged’ for the purpose of this study. Athletes who did not meet the discharge criteria during the assessment, but who decided to RTS despite this, were classified as ‘not fully discharged’.

Data collection

Strength

Concentric isokinetic tests were performed on both the involved and uninvolved quadriceps and hamstrings. Athletes were asked to perform five repetitions of knee extension and flexion for each leg at 60°/s and 180°/s, and 20 repetitions at 300°/s. A Biodex dynamometer (System 4, Biodex Medical Systems, Shirley, New York, USA) was used and peak torque, per cent of peak torque to body weight, average power and hamstrings to quadriceps peak torque ratio were recorded.

Agility

A running t test was performed, which evaluates agility during running with changes of direction. Athletes were asked to run forward for 10 m, then change to side-steps to the right for 5 m, then 10 m of side-steps to the left, followed by 5 m of side-steps to the right, ending with 10 m of backwards running (figure 2).22 23 Three repetitions were performed at maximum speed and the average time for the three repetitions was calculated.

Hop performance

Single and triple hop tests for distance were used.24–26 These tests measure the distance that an individual can cover while jumping on one leg. Athletes were instructed to perform a hop for a distance with each leg three times and the distance was recorded only if the landing was successful, without losing balance. The same procedure was followed for triple hop for distance test where athletes had to perform three continuous hops. Finally, the crossover hop test was performed. This test is a modified triple hop test during which athletes had to cross a line while performing the three hops. The results were recorded and the limb symmetry index was calculated as the hop distance of the involved leg divided by the hop distance of the uninvolved leg multiplied by 100.

Demographic and surgical information

We recorded age at time of injury, weight and height, type of sport participation, duration of rehabilitation, date of surgery, and the limb symmetry index was calculated as the hop distance of the involved leg divided by the hop distance of the uninvolved leg multiplied by 100.

Table 1 Discharge tests and criteria used during the study period

<table>
<thead>
<tr>
<th>Six-part return to sport tests</th>
<th>Discharge permitted when each of these criteria was met</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isokinetic test at 60, 180 and 300°/s</td>
<td>Quadriceps deficit &lt;10% at 60°/s, Limb symmetry index &gt;90%</td>
</tr>
<tr>
<td>Single hop</td>
<td>Limb symmetry index &gt;90%</td>
</tr>
<tr>
<td>Triple hop</td>
<td>Limb symmetry index &gt;90%</td>
</tr>
<tr>
<td>Triple crossover hop</td>
<td>Fully completed</td>
</tr>
<tr>
<td>On-field sports-specific rehabilitation</td>
<td></td>
</tr>
<tr>
<td>Running t test</td>
<td>&lt;11 s</td>
</tr>
</tbody>
</table>

Criteria were set according to the literature at the start of the study.
discharge date, graft type used, secondary injuries at the time of primary ACL injury (e.g., cartilage lesions, meniscal tears, medial collateral ligament injuries) and whether or not the athletes met the discharge criteria.

Statistical analysis
All data were imported into SPSS V.21 for statistical analyses. All continuous variables were tested for normality and presented as the mean with SD. Between-group differences (ACL graft rupture vs no ACL graft rupture) were examined using an independent samples t test. To control the false discovery rate (FDR) arising from multiple comparisons, we used the Benjamini–Hochberg procedure with FDR = 0.25 and computed adjusted p values. Any value of <0.25 was considered significant. For categorical variables, the association with ACL graft rupture was examined using a χ² test. Any athlete characteristic or isokinetic parameter with a p value <0.05 was included in a backward stepwise Cox regression model to ascertain the effect of the variable on the likelihood that athletes had an ACL graft rupture. HRs with 95% CIs were reported. A p value of <0.05 was considered statistically significant for the Cox regression.

RESULTS
Athletes (N=158) returned to their previous competitive level a mean of 229 days after surgery (range 116–513 days). Of these, 26 (16.5% of 158) sustained an ACL graft rupture and 11 (7.0% of 158) sustained a contralateral rupture of their native ACL. Of the athletes who sustained an ACL graft rupture during the follow-up period, 17 (65.4% of 26) were re-injured within the first 6 months after RTS. The median time from RTS until ACL graft rupture was 105 days. Of the 158 athletes, 141 (89%) were followed up for at least 6 months and 112 (71%) for at least 12 months. Figure 3 depicts the cumulative prevalence of ACL graft ruptures.

Table 2 also shows the rehabilitation duration, secondary injuries and graft type of these two groups. Nineteen (73.1%) of the 26 athletes who had an ACL graft rupture had a hamstring graft and seven (26.9%) had a BPTB graft. Of all athletes who received a hamstring graft (n=108), 17.6% suffered a re-rupture compared with 14.0% of all athletes who received a BPTB graft (n=50).

Of the 158 athletes included, 116 (73%) were fully discharged and 42 (27%) were not. Among those fully discharged, 12 (10.3% of 116) suffered an ACL graft rupture compared with 14 (33.3% of 42) of those who were not fully discharged (p<0.001).

Table 3 shows the comparison of isokinetic and functional tests between the groups. Between-group differences were found in the per cent of peak torque to body weight of the involved hamstrings at 60°/s, the hamstring to quadriceps ratio of the involved leg at 60°/s, the average power of the involved hamstrings at 60, 180 and 300°/s and the per cent of peak torque to handball. Table 2 also shows the rehabilitation duration, secondary injuries and graft type of these two groups.

Table 2 shows the anthropometric, injury and sport characteristics of the athletes. No significant differences were observed between the injured and non-injured groups. In both groups, football was the most frequently played sport, followed by handball. Table 2 also shows the rehabilitation duration, secondary injuries and graft type of these two groups. Nineteen (73.1%) of the 26 athletes who had an ACL graft rupture had a hamstring graft and seven (26.9%) had a BPTB graft. Of all athletes who received a hamstring graft (n=108), 17.6% suffered a re-rupture compared with 14.0% of all athletes who received a BPTB graft (n=50).

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Table 3  Isokinetic and functional test results

<table>
<thead>
<tr>
<th>Variables</th>
<th>No ACL graft rupture (n=132)</th>
<th>ACL graft rupture (n=26)</th>
<th>p Value</th>
<th>Unadjusted</th>
<th>Benjamini–Hochberg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak torque to body weight at 60(^\circ)/s (%)</td>
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<td></td>
<td></td>
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<tr>
<td>Uninvolved quadriceps</td>
<td>331 (62)</td>
<td>339 (73)</td>
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<td>0.79</td>
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<tr>
<td>Involved quadriceps</td>
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<td>309 (74)</td>
<td>0.65</td>
<td>0.76</td>
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<tr>
<td>Uninvolved hamstrings</td>
<td>180 (28)</td>
<td>174 (30)</td>
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<tr>
<td>Involved hamstrings</td>
<td>172 (31)</td>
<td>159 (33)</td>
<td>0.05</td>
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<tr>
<td>Bilateral difference at 60(^\circ)/s (%)</td>
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<tr>
<td>Quadriceps</td>
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<td>−9 (14)</td>
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<td>Hamstring to quadriceps ratio at 60(^\circ)/s (%)</td>
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<tr>
<td>Involved leg</td>
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<td>53 (11)</td>
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<tr>
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<tr>
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<td></td>
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<tr>
<td>Uninvolved quadriceps</td>
<td>163 (35)</td>
<td>160 (38)</td>
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<td>0.79</td>
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<tr>
<td>Involved quadriceps</td>
<td>149 (32)</td>
<td>146 (37)</td>
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<tr>
<td>Uninvolved hamstrings</td>
<td>97 (19)</td>
<td>93 (18)</td>
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<tr>
<td>Involved hamstrings</td>
<td>91 (19)</td>
<td>79 (21)</td>
<td>0.006</td>
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<td>Peak torque to body weight at 180(^\circ)/s (%)</td>
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<td>Uninvolved quadriceps</td>
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<tr>
<td>Involved quadriceps</td>
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<td>207 (41)</td>
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<td>Uninvolved hamstrings</td>
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<td>137 (24)</td>
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<td>129 (27)</td>
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<td>Bilateral difference at 180(^\circ)/s (%)</td>
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<tr>
<td>Quadriceps</td>
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<td>−12 (12)</td>
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<tr>
<td>Hamstrings</td>
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<td>−5 (15)</td>
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<tr>
<td>Hamstring to quadriceps ratio at 180(^\circ)/s (%)</td>
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<tr>
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<td>Uninvolved leg</td>
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<td>Average power at 180(^\circ)/s (W)</td>
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<td></td>
<td></td>
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<tr>
<td>Uninvolved quadriceps</td>
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<tr>
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<td>172 (37)</td>
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<td>Involved hamstrings</td>
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<td>Peak torque to body weight at 300(^\circ)/s (%)</td>
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<tr>
<td>Uninvolved quadriceps</td>
<td>189 (27)</td>
<td>185 (33)</td>
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<td>0.79</td>
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<tr>
<td>Involved quadriceps</td>
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<td>167 (30)</td>
<td>0.16</td>
<td>0.51</td>
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<td>Uninvolved hamstrings</td>
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<td>126 (23)</td>
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<td>Bilateral difference at 300(^\circ)/s (%)</td>
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<tr>
<td>Quadriceps</td>
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<tr>
<td>Hamstring to quadriceps ratio at 300(^\circ)/s (%)</td>
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<tr>
<td>Involved leg</td>
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<td>Uninvolved leg</td>
<td>71 (11)</td>
<td>70 (15)</td>
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<td>Average power at 300(^\circ)/s (W)</td>
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<tr>
<td>Uninvolved quadriceps</td>
<td>303 (60)</td>
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<td>259 (51)</td>
<td>0.11</td>
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<td>Uninvolved hamstrings</td>
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<td>172 (48)</td>
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<tr>
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<td>Work fatigue at 300(^\circ)/s (%)</td>
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<td>Uninvolved quadriceps</td>
<td>34 (9)</td>
<td>34 (15)</td>
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<td>Involved quadriceps</td>
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<td>32 (9)</td>
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<td>Uninvolved hamstrings</td>
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<td>35 (11)</td>
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<tr>
<td>Involved hamstrings</td>
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<td>34 (16)</td>
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<tr>
<td>Average t test time (s)</td>
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<td>10 (1)</td>
<td>0.92</td>
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<tr>
<td>Limb symmetry index (%)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Single hop</td>
<td>97 (6)</td>
<td>99 (5)</td>
<td>0.16</td>
<td>0.48</td>
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</tr>
<tr>
<td>Triple hop</td>
<td>98 (7)</td>
<td>99 (4)</td>
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<tr>
<td>Crossover hop</td>
<td>99 (7)</td>
<td>99 (8)</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

Data are presented as mean (SD). Bold type indicates statistical significance.
body weight of the involved hamstrings at 300%/s. These vari-
able, as well as whether or not patients were fully discharged, were included in the Cox regression model.

The Cox regression model identified hamstring to quadriceps ratio at 60°/s and whether or not an athlete had been fully dis-
charged as risk factors for an ACL graft rupture. Those who had a lower hamstring to quadriceps ratio had a greater risk of ACL
graft rupture (HR 10.6 per 10% difference, 95% CI 10.2 to 11, p=0.005), and those who were not fully discharged had a four
times greater likelihood of sustaining an ACL graft rupture (HR

4.1, 95% CI 1.9 to 9.2, p<0.001).

**DISCUSSION**

We found that the athletes who did not meet the specific dis-
charge criteria before RTS and were not fully discharged from
ACLR rehabilitation by the surgeon had a four times greater risk
of sustaining an ACL graft rupture (73%) compared with those
who returned to their sport after passing the RTS criteria
(27%).

Graft rupture rates ranging from 6% to 25% have been
reported in the literature. Bourke et al followed 186 patients for 15 years after isolated hamstring graft ACLR
surgery and reported an 18% rate of ipsilateral ACL graft
rupture for all age groups (average age 25.8 years). In a 2-year
follow-up study of 98 patients who underwent ACLR, Kamien
et al reported a 25% rate of graft failure for patients younger
than 25 years. Therefore, the observed overall graft rupture rate
of 17% observed in our study is comparable to previous liter-
ature when taking into account the fact that every patient
included in our study was a professional athlete of average age
22 years who went back to his pre-injury level of sports
participation.

**Factors that might influence the risk of graft rupture**

One factor that is often considered to contribute to an increased
risk of ACL graft rupture is premature RTS without following
and meeting specific criteria. In our study, 70% of the ACL graft
ruptures occurred during the first 6 months after RTS, which
extends previous findings to the Gulf Region population.

One explanation for the increased risk of ACL graft ruptures
among athletes in our study who did not pass the discharge cri-
teria could be impaired neuromuscular function. In a previous
study, people with ACL injury who did not pass their RTS cri-
teria had larger kinematic and kinetic asymmetries between
limbs and used a gait strategy similar to athletes early after ACL
rupture. The RTS tests and criteria we applied rigorously
related to the known measures of biomechanical impairments.
This suggests that neuromuscular asymmetries during dynamic
movement may not only affect sport performance (and therefore
lead to failing the RTS criteria), but may also predict the risk of
a graft rupture.

We also identified a low hamstring to quadriceps strength
ratio as a risk factor for ACL graft rupture. Strength, particu-
larly quadriceps strength, has always been considered an important
aspect of ACL rehabilitation and has been identified as a pre-
requisite for a successful outcome. Hamstring to quadriceps
strength imbalances have also been suggested as a possible risk
factor for ACL injuries, although there is limited direct
evidence to support this. The hamstring muscles act as agonists to
the ACL by resisting the anterior tibial displacement that results
from quadriceps muscle forces at the knee. For this reason, the
hamstring strength and the ratio of hamstring muscle strength to
quadriceps muscle strength is often discussed as a risk factor for
primary ACL rupture. Our results provide tantalising data
suggesting this phenomenon may also be at play in the recon-
structed ACL.

**Criteria for RTS**

Time to RTS (a surrogate measure of the strength and matur-
ation of the ACL graft) is considered an important factor in RTS
decision-making. The current clinical dogma is that RTS should
not be permitted within 6 months of reconstruction. Although there is little evidence to substantiate this, Grindem
and colleagues recently reported a 50% reduction in risk of
knee re-injuries (all injuries, not only ACL) for each month that
RTS is delayed beyond 6 months. However, in addition to time
as a criterion, knee function evaluated by RTS tests is also a key
element in the decision-making process.

Several batteries of tests and discharge criteria are described
for RTS. These tests assess both function and strength. The maximum bilateral deficit recommended as acceptable for
RTS clearance for functional and strength tests is between 10% and
15%. The RTS criteria of our study were also in line with
studies suggesting that a limb symmetry index of 90% in
all hop tests and 85% in isokinetic strength tests be used. It
has been hypothesised that meeting these criteria implies a good
recovery of muscle strength and neuromuscular control, and
therefore ensures safe RTS.

The test batteries used to guide RTS are reliable and able to
discriminate between people with ACL injury and healthy con-
trols. However, no previous prospective studies have exam-
ined whether these RTS criteria predict those who are at
increased risk of ACL graft rupture. Given the high incidence
of ACL graft ruptures, there is legitimate concern over the clinical
criteria that are used to determine clearance to RTS.

In our study, completing the rehabilitation programme and
meeting our discharge criteria was associated with substantially
lower odds of suffering an ACL graft rupture. Meeting stringent
RTS criteria may reduce the risk of a future ACL graft rupture,
and suggests that a RTS test battery with associated criteria may
be a useful component of the RTS decision-making process.
However, only 41% of surgeons report using strength or func-
tional tests to assist their RTS decision-making.

Although our multiple regression analysis did not identify
hamstring weakness alone as a risk factor for graft rupture, the
univariate tests showed a consistent trend of a hamstring
strength deficit being associated with increased risk across all of
the six strength variables tested (p=0.04–0.08). We acknow-
ledge that the current study was exploratory, not hypothesis-
driven, and a large number of candidate risk factor variables
were explored in the univariate analyses. As indicated by the
adjusted p values, these findings must therefore be interpreted
with caution. Nevertheless, these data suggest that sufficient
hamstring strength and, consequently, an appropriate balance
between hamstrings and quadriceps muscle strength is an
important goal of ACL rehabilitation and should be used as a
RTS criterion. However, these results need to be confirmed in
future studies.

Our strength results cannot be compared with previous
research since no studies have examined strength as a risk
factor for ACL graft rupture. However, some research is avail-
able on strength as a risk factor for primary ACL
injury. These studies confirm the importance of a balanced
hamstring and quadriceps strength in people with
ACL injury and are consistent with our findings. Raschner et al, after retrospectively following 370 alpine skiers, con-
cluded that hamstring to quadriceps ratio was significantly
higher among athletes who did not sustain an ACL injury.

Uhorchak et al.\(^6\) after a 4-year follow up of 895 USA military academy cadets, were not able to identify any of the strength ratios or parameters as a possible risk factor for an ACL injury. Although there were no significant differences in hamstring to quadriceps strength ratios, they reported a relatively higher risk of non-contact ACL injury for men who displayed greater eccentric quadriceps strength.

Limitations and strengths of the study
Our study has some limitations. First, the cohort examined comprised professional male athletes, mainly ethnic Arabs, which limits extrapolation to different populations. Second, the number of subjects included in this study was limited (N=158) and the number of ACL re-injured athletes was also small (n=26). Third, limited variables were tested (strength and functional tests) and no movement analysis or neuromuscular assessment was performed. Follow-up was a minimum of 6 months for those who did not have an ACL graft rupture. Nevertheless, the mean follow-up was 786 days and, since the graft rupture rate is highest in the first 12 months (71% of athletes included had passed this mark), we would argue that this justifies the approach taken. Whether the personality of individuals who do not complete their rehabilitation but RTS is associated with a greater risk of ACL graft rupture is something about which we are not in a position to comment.

A significant strength of this study is the tightly controlled and standardised discharge tests and criteria. All clinical staff associated with ACLR rehabilitation worked using a standardised discharge procedure. This approach minimised the variability of outcome associated with individual variations in rehabilitation. In addition, the study setting ensured that we registered all ACL graft ruptures.

CONCLUSION
Patients who did not meet the discharge criteria before returning to professional sport had a four times greater risk of sustaining an ACL graft rupture than those who passed the RTS criteria. In addition, hamstring strength deficits were associated with a greater risk of sustaining a graft tear.

References

1. Barber-Westin SD, Novyes FR. Factors used to determine return to unrestricted sports activities after anterior cruciate ligament reconstruction. *Arthroscopy* 2011;27:1692–705.