Reduction in re-rupture rates following implementation of return-to-sport testing after anterior cruciate ligament reconstruction in 313 patients with a mean follow-up of 50 months


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ABSTRACT

Objectives: The objective of this study was to assess the mid-term effectiveness of a return to sport (RTS) test in relation to preventing anterior cruciate ligament (ACL) re-rupture and contralateral ACL injury following ACL reconstruction (ACLR). Furthermore, this study aimed to assess the timing of passing a, RTS-test after surgery, and the effect age has on RTS outcomes.

Methods: Patients undergoing ACLR between August 2014 and December 2018 took an RTS-test following rehabilitation. The RTS-test consisted of the Anterior Cruciate Ligament Return to Sport After Injury Scale, a single-leg hop, a single-leg triple hop, a single-leg triple cross-over hop, a box-drop vertical jump down, a single-leg 4-rep max-incline leg press, and a modified agility T test. RTS-passing criteria were >90% limb symmetry index in addition to defined takeoff and landing parameters. Mid-term review assessed sporting level, ACL re-injury, and contralateral ACL injury.

Results: A total of 352 patients underwent RTS-testing, following ACLR with 313 (89%) contactable at follow-up, a mean of 50 months (standard deviation: 11.41, range: 28–76) after surgery. The re-rupture rate was 6.6% after passing the RTS-test and 10.3% following failure (p = 0.24), representing a 36% reduction. Contralateral ACL injury rate after surgery was 6% and was 19% lower in those passing the RTS test. The mean age of patients passing their first RTS-test was significantly higher than that of those who failed (p = 0.0027). Re-ruptures in those who passed the RTS test first time occurred late (>34 months), compared to those who failed first time, which all occurred early (<33 months) (p = 0.0015). The mean age of re-rupture was significantly less than those who did not sustain a re-rupture (p = 0.025).

Conclusion: Passing a RTS-test following ACLR reduces ACL re-rupture by 36.21% and contralateral ACL injury by 19.15% at mid-term follow-up. Younger patients are more likely to fail a RTS-test and are at higher risk of contralateral ACL rupture.

Level III Evidence.

What are the new findings

- Successfully passing this return-to-sport (RTS) test reduces anterior cruciate ligament re-rupture and contralateral anterior cruciate ligament injury rates
- Passing this RTS test may prevent early re-ruptures
INTRODUCTION

Anterior cruciate ligament reconstruction (ACLR) is a commonly performed procedure with around 3000 being undertaken in New Zealand in 2020 [1]. The majority of reconstructions occur in the younger active patients who regularly undertake competitive sport [1,2]. Timing until return to sport (RTS) following ACLR is one of the most commonly asked questions by patients at diagnosis. Timelines are variable and are dependent on multiple factors. A meta-analysis from 2016 found that RTS timing varied between 6 months and over a year [3]. Earlier RTS, especially in younger patients, appears to be a significant risk factor for ACL re-rupture [4,5]. However, age and timing are not the only non-surgical factors that may predispose to re-injury. Static and dynamic testing of strength and movement control, clinical review, and patient-reported outcome measures (PROMs) have all been utilised alone or in combination, following rehabilitation, to determine when it is appropriate to return to sport. Despite multiple testing protocols being described and a recent meta-analysis, there remains no consensus around a battery of testing [2]. Furthermore, there is no absolute certainty that passing an RTS test advocates an immediate return or a lower ACL re-rupture rate [1,6–8]. Dynamic tests are less easily standardised, and there is established variability in measurements between observers. Required test performance in relation to returning to sport may also vary between different sports and their performance attributes.

Ultimately, RTS testing ideally reduces risk of re-injury in the short and long terms whilst allowing patients to return at their desired level.

The primary purpose of this study was to assess the mid-long-term effectiveness of a novel RTS test in relation to preventing ACL re-rupture and contralateral ACL injury following ACLR at a single centre in New Zealand. Secondary objectives were to assess the timing of successfully passing an RTS test after surgery and the effect that age has on RTS-test outcomes.

We hypothesised that undertaking an RTS test would reduce ACL re-rupture rates and contralateral re-rupture rates.

MATERIALS AND METHODS

All patients who attended the Unisports clinic in Auckland, New Zealand, and underwent ACLR or revision ACLR with or without meniscal repair between August 2014 and December 2018 were invited to undertake an RTS test. Patients with neurovascular injuries, tibial plateau fractures, or those undergoing multiligament reconstructions or ACLR combined with an osteotomy or lateral tenodesis were excluded. Patients were operated on by one of four surgeons at the practice (BT, JS, MR, SW) using ipsilateral hamstring or patella tendon grafts (depending on informed patient choice after discussion with their surgeon). All operations were performed under general anaesthetic, utilising a high thigh tourniquet, and were arthroscopically assisted. Patients underwent rehabilitation with a physiotherapist of their choice following surgery in order for the study to have realistic rehabilitation variability and therefore transferable results. One surgeon braced all ACL reconstructions regardless of meniscal repair until 6 weeks. The remaining 3 surgeons did not brace, allowing free Range of Motion (ROM). Weight bearing was limited in those with meniscal root or radial meniscal tears but was allowed as tolerated in all other cases. The operating surgeon routinely reviewed patients at 6 weeks, 3 months, 6 months, and 1 year after surgery. Once agreement between physiotherapist, surgeon, and patient was reached regarding appropriateness for possible return to sport, patients underwent a standardised RTS test by a single physiotherapist (SaW) at the Unisports Clinic.

Given that there was no widely accepted consensus on RTS-test battery, our RTS test was designed following a review of the current literature and analysis of previous RTS tests and test validations [9–16]. The test included validated static and dynamic variables with validated subjective patient input, did not require expensive high-tech equipment and was easily transferable between institutions.

The test program consisted of the Anterior Cruciate Ligament Return to Sport After Injury Scale (ACL-RSI), a single-leg hop for distance, a single-leg triple hop for distance, a single-leg triple cross-over hop for multidirectional movement control, a box-drop vertical jump for control, a single-leg 4-rep max-incline leg press for strength, and a modified agility T test for reaction to demanded change of direction (see Fig. 1). Patients were asked to allow 60 min for the test; this included time for results and post-test patient feedback.

The procedure for jump tests was standardised for all patients. All patients watched a short video, which demonstrated a clean terminal landing pattern and poor terminal landing pattern; they were not coached on how to achieve this. Patients were given 3 trial attempts on each limb for familiarity, beginning on the non-operated leg and then alternating. Distance measurements were taken from the test starting point to the heel on landing and were measured to the nearest mm. Three measurements were taken for each test and were averaged and compared.

Fig. 1. – Modified T-test to assess directional change. Patients start and finish at both sides as each run through has only 1 directional change. Cones are placed 15 m apart.
using limb symmetry index. Patients who were unable to complete linear hop tests due to their knee did not progress to be tested on multidirectional hop tests due to re-injury risk. To achieve a pass, we set a standard of ≥90% limb symmetry index in addition to satisfying certain take-off and landing parameters. On take-off and landing, patients must not undertake excessive asymmetric hip adduction or internal rotation, knee valgus, lateral deviation, or excessive forward flexion of the trunk. Failure was automatic on loss of balance, touching the floor with the other limb, or an additional short hop after landing (see Fig. 2). These patients were referred back to their physiotherapist with outcomes of the test for additional targeted physiotherapy. Failure of 1 or more tests determined overall test failure. Retesting was undertaken when the patient and physiotherapist agreed that the issues had been addressed.

The ACL-RSI was performed to include a PROM, which could also be utilised to determine any correlation between the patients’ psychological confidence and physical performance in the test.

Once patients passed the RTS test, they were encouraged to return to full training and contact prior to returning to competition. We believe this may have been variable depending on participation level and therefore classified RTS as the time when the test was passed or failed for the final time.

All patients were contacted at a minimum of 1 year after their final RTS test to determine re-injury rates and level of sport. Tegner score was filled in at follow-up to compare to the pre-operative score, which is taken as part of routine practice [17]. Re-ruptures and contralateral injuries were confirmed on review of new magnetic resonance imaging.

RTS-test data were recorded in an Excel spreadsheet alongside patient, surgery, and re-injury demographics (date of birth, sex, injury date, surgery date, date of RTS test, test pass/failure, further RTS test/non-attendance). Ethical review was undertaken by the Health and Disability Ethics Committee, New Zealand. Informed consent was taken from all patients for use of data. No funding was required for this study.

All data were analysed for overall RTS pass and failure rates and incidence of ACL re-injury or contralateral ACL injury. Subgroup analysis of RTS outcome, ACL re-injury, and contralateral injury in relation to gender, age subgroups, graft type, and Tegner were undertaken. Analysis of the RTS test was also undertaken to identify outcomes of individual tests in relation to re-ruptures, time following surgery, and age and gender subgroups. Continuous variable demographic data were analysed with a one-way analysis of variance test or paired T-test. Categorical data were analysed with a chi-squared test. Statistical significance for all comparisons was set at 0.05.

Fig. 2. Pass and fail landing patterns. A. Shows a controlled landing pattern. B. Shows an uncontrolled landing pattern, with left knee valgus, left hip drop, and compensatory trunk lean.
RESULTS

A total of 352 patients underwent ACLR and RTS testing between August 2014 and December 2018. All patients were contacted in December 2020 for review. At follow-up, 313 patients (191 male:122 female) were available, giving a follow-up rate of 89% at a mean follow-up time of 50.36 months (standard deviation [SD]: 11.41, range: 28–76) after surgery.

Graft choice agreed between surgeon and patient was ipsilateral 4-strand hamstring (semitendinosus and gracilis) in 195 cases and patella tendon in 118 cases. No synthetic or allografts were used; 294 cases were primary ACLR, and 19 were revision ACLR. The mean age was 23.85 years (SD: 8.48, range: 9.67–55.92).

All patients underwent at least one RTS test. Initial RTS testing was performed at a mean of 322 days after surgery (SD: 87.53, range: 142–231). Second RTS testing for those who failed the initial test was performed at a mean of 388 days after surgery (SD: 90.11, range: 231–617).

A total of 85 patients (27.16%) passed the initial RTS test; 228 patients (72.84%) failed the initial RTS test and were all offered a second test. Seventy-five (32.89%) patients declined a second test after initial failure. A total of 153 patients (66.67%) underwent a second RTS test, of which 112 patients (73.20%) passed, and 41 patients (26.80%) failed. Overall, 197 patients (62.94%) passed the RTS test (Table 1, Fig. 3). We were unaware of any patient who attended for an RTS test and had already returned to sport.

There were 25 graft re-ruptures reported at follow-up, giving an overall re-rupture rate of 7.99%. The re-rupture rate was 6.60% if the RTS test was passed and 10.34% if the test was not passed (p = 0.24). There were 24 ruptures in the primary ACLR group and 1 re-rupture in the revision ACLR group (p = 0.65). This represented a 36.21% reduction in ACL re-rupture and a 19.15% reduction in contralateral ACL rupture during the study period by passing an RTS test. (See Table 2).

The risk ratio of a re-rupture if the RTS test was passed at either attempt compared to if it was never passed was 0.6379 (0.3012–1.3509), p = 0.2403.

Graft re-ruptures

Time to ACL re-rupture following surgery was significantly longer in those who passed the RTS-test first time than in those who failed (p = 0.015). See Table 3. There was no difference in time to rupture between those who failed and those who subsequently passed or never passed the RTS test. All re-ruptures occurred in patients under 30 years of age, and when compared to those who did not suffer re-rupture, younger age was a significant factor (p = 0.025).

Timing

There was no statistically significant difference in age between the timing of testing of the pass and fail groups. The only statistically significant difference in time to successfully passing the RTS test was when:

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Passed the 1st RTS</th>
<th>Failed the 1st and attended the 2nd RTS</th>
<th>Failed the 1st RTS and DNA</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>26.08 (8.03, 14.58–49.42)</td>
<td>22.22 (8.01, 9.67–52.50)</td>
<td>24.65 (9.31, 10.92–55.92)</td>
<td>&lt;0.002* (1:2)</td>
</tr>
<tr>
<td>Male</td>
<td>47</td>
<td>106</td>
<td>44</td>
<td>n.s.</td>
</tr>
<tr>
<td>Female</td>
<td>38</td>
<td>53</td>
<td>31</td>
<td>n.s.</td>
</tr>
<tr>
<td>Hamstring graft</td>
<td>52</td>
<td>95</td>
<td>48</td>
<td>n.s.</td>
</tr>
<tr>
<td>Patella tendon graft</td>
<td>33</td>
<td>58</td>
<td>27</td>
<td>n.s.</td>
</tr>
<tr>
<td>RTS test after surgery (days)</td>
<td>319.32 (80.14, 211–535)</td>
<td>325.23 (84.54, 184–567)</td>
<td>321.84 (101.24, 142–577)</td>
<td>0.67</td>
</tr>
<tr>
<td>Follow-up (months)</td>
<td>51.04 (11.58, 30–52)</td>
<td>50.20 (11.07, 28–74)</td>
<td>49.64 (11.82, 28–76)</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Values are mean (± standard deviation, range) unless otherwise indicated.

DISCUSSION

This study reports a novel RTS-testing protocol following ACLR at mid-term duration of follow-up after surgery with a low loss to follow-up rate of only 11%.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>Passed the 2nd RTS</th>
<th>Failed the 2nd RTS</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.89 (8.02, 11.42–52.50)</td>
<td>20.39 (7.77, 9.67–48.58)</td>
<td>0.09</td>
</tr>
<tr>
<td>Male</td>
<td>73</td>
<td>27</td>
<td>n.s.</td>
</tr>
<tr>
<td>Female</td>
<td>39</td>
<td>14</td>
<td>n.s.</td>
</tr>
<tr>
<td>Hamstring graft</td>
<td>70</td>
<td>25</td>
<td>n.s.</td>
</tr>
<tr>
<td>Patella tendon graft</td>
<td>42</td>
<td>16</td>
<td>n.s.</td>
</tr>
<tr>
<td>RTS test after surgery (days)</td>
<td>379.72</td>
<td>409.71</td>
<td>0.07</td>
</tr>
<tr>
<td>Follow-up (months)</td>
<td>49.57</td>
<td>52.44 (9.71, 32–70)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Values are mean (±standard deviation, range) unless otherwise indicated.

RTS – return to sport test.
DNA – did not attend.
n.s. – not significant.
The first statistically significant finding of this study was the higher mean age of patients who passed the first RTS test than in those who failed. No patient under the age of 14.58 years passed the RTS test on the first attempt, and the mean age for passing first time was 26.08 years. Few studies have directly reported age in relation to RTS-test outcomes. Those that have report higher or similar pass rates in younger patients completing an RTS-test battery [18–21]. Given the higher rates of re-rupture in younger patients, this seems paradoxical that they would pass testing and RTS earlier [22–27]. Many of the RTS studies have a high loss to follow-up, and complications such as re-rupture are excluded from many studies or not analysed in enough detail. This presents a significant chance that the studies are underpowered, given the low overall re-rupture rates. Many of the studies reviewing RTS testing following ACLR also use the same or a majority of another patient cohort [2,4,20,28,29].

The second statistically significant finding of this study was that those who fail to pass the RTS test and suffer a graft re-rupture do so at a much earlier time following surgery than those who pass their first RTS test and sustain a re-rupture. No patient who passed the RTS test first ruptured before 34 months after surgery; however, all those who failed to pass the RTS-test and re-ruptured did so before 33 months. This raises a question as to whether the early re-ruptures (all of which occurred in those unable to pass the RTS test) are a failure of rehabilitation and the later re-ruptures (all of which occurred in those who passed the RTS test first time) are new injuries after successful treatment. This concept does not seem to have been addressed within the literature before. This concept has significant bearing as if proven it would add considerable evidence in favour of RTS testing as a re-injury prevention tool. It is difficult to compare our findings with other RTS-test studies as few have a mid-long-term follow-up. However, there is limited evidence that failure to pass an RTS test results in an early re-rupture [8,28,30]. Long-term follow-up of other patient cohorts is required to validate our finding.

The third statistically significant finding of this study was a younger mean age of re-ruptures relative to those who did not suffer re-rupture. All re-ruptures occurred under the age of 30 years, with a mean age skewed towards the younger end of the cohort range. This is in keeping with previous studies that have consistently demonstrated higher re-rupture rates in younger patients following ACLR [22,25–27].

Table 3
Demographics of patients who re-ruptured.

<table>
<thead>
<tr>
<th>Passed the 1st RTS</th>
<th>Failed the 1st and passed the 2nd RTS</th>
<th>Failed the 1st and 2nd RTS</th>
<th>Failed the 1st RTS and DNA</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21.48 (1.70, 19.92–25.42)</td>
<td>19.42 (4.39, 14.92–27.08)</td>
<td>18.36 (4.60, 13.08–24.75)</td>
<td>21.40 (4.70, 16.67–29.92)</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Female</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Hamstring graft</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Patella tendon graft</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>RTS test after surgery (days)</td>
<td>347.00 (58.24, 282–406)</td>
<td>376.22 (52.01, 317–436)</td>
<td>446 (121.80, 335–617)</td>
<td>321.30 (62.78, 255–448)</td>
</tr>
<tr>
<td>Re-rupture after surgery (months)</td>
<td>39.50 (5.45, 34–47)</td>
<td>25.78 (14.6, 10–44)</td>
<td>24.75 (6.18, 20–33)</td>
<td>19.00 (7.71, 10–33)</td>
</tr>
<tr>
<td>Re-rupture after the final RTS test (months)</td>
<td>28.47 (6.48, 23.90–38.07)</td>
<td>14.05 (14.61, 0.56–33.70)</td>
<td>10.41 (8.17, 5.65–22.62)</td>
<td>9.53 (8.28, 0.16–23.90)</td>
</tr>
</tbody>
</table>

Values are mean (±standard deviation, range) unless otherwise indicated.

RTS = return to sport test.

DNA = did not attend.

n.s. denotes not significant.

*Significant difference at the 0.05 level of significance.
reconstruction remains unclear but is likely multifactorial \[31-34\]. This suggests that the battery of RTS testing used in this study does not selectively reduce re-rupture rates in younger patients. Future consideration of a validated battery of tests specific to younger patients may be an area for research.

This study found no correlation or statistical difference between the type of graft used for ACLR and the time to RTS test after surgery, or RTS test outcome or re-rupture rate. This does not imply that graft type is not an important consideration for both surgeon and patient, rather it does not appear to have a material effect in relation to RTS testing.

Contralateral ACL rupture occurred in 6.07% of patients during this study and had historically occurred in an additional 5.11% of patients prior to this study. Previous studies have also reported high rates of contralateral ACL injuries, and this adds to the evidence highlighting the importance of considering potential deficits in the contralateral limb during rehabilitation \[35,36\]. This study demonstrated a relative risk reduction of 19.14% in contralateral ACL ruptures if the RTS test was passed, but this was not significant.

Much of the current literature centres around RTS testing at a set time after surgery rather than when patients and clinicians agree on potential completion of successful rehabilitation \[18-21\]. Time-based review may be biasing RTS pass/fail and re-rupture rates by assessing patients too early. In our study, no patients passed an RTS test before 7 months, and the mean time of patients who passed their first test was over 10 months. This is in keeping with previous studies, in which timing on its own was considered a poor predictor of when patients can RTS but may provide some timing evidence towards a potential floor effect \[6\].

Why and when people rupture their ACL or sustain a re-rupture following reconstruction remains unclear but is likely to be multifactorial. Certain people may have predisposing anatomical, biological, or physiological risk factors that have been previously linked with ACL injury, but not everyone is with these risk factors ruptures \[6\]. Conversely, some people have none of these risk factors yet suffer rupture. Two meta analyses of recent RTS-testing studies indicated that passing an RTS test decreases the re-rupture rate but that this is not a statistically significant effect \[2,37\]. This study is in line with those findings; a relative risk reduction in re-rupture rates of 36.21% was seen in our study when passing an RTS test, but this was not statistically significant. Given the low overall rates of re-rupture, it is likely that current studies, including this one, are underpowered.

The 4% difference in re-rupture rates may not be statistically significant, but we believe that the time and cost of performing an RTS test is still appropriate, given the 36.21% difference in re-injury between the groups. In those patients, this prevention represents an important health, time, and cost-saving in both the immediate and long-term when time off work, time away from sports, and joint health are considered.

Passing or failing an RTS test appears to place people in a higher/lower risk group for re-injury, but it is difficult to ascertain if this is cause or effect. In this study, patients self-selected to return for a test or not following failure. It may be that those who passed first time or returned and passed were more compliant or had more insight into their rehabilitation. Alternatively, there may have been an underlying physiological, anatomical, or chronological difference, or a social or healthcare factor that makes certain individuals more likely to reattend.

Tegner scores were used to determine if patients returned to sport at the same level they participated prior to injury. This was statistically significant in demonstrating that overall, patients returned to sport at a reduced level. However, the relevance of this as an outcome in connection to the ACLR and RTS test is unclear. The Tegner score has not been validated in younger patients, and there is evidence to show that children do not comprehend the language and therefore levels being described \[38\]. Some of the older patients at follow-up had altered their level of activity based on lifestyle factors unrelated to the surgery such as career changes, starting a family, or taking planned retirement from sport. We were unable to account for these variables statistically and therefore see this as a study limitation and advise careful interpretation of level of activity outcomes.

Furthermore, a limitation of this study was the lack of a priori sample calculation in the setting of the use of a novel RTS-test battery, which requires validation in a larger study. Further work is also required to determine if the battery of testing should be sport-specific or not. Another limitation was in the lack of recording of excluded patients either by their own choice or because of the inclusion/exclusion criteria.
The final limitation was in our use of the collected ACL-IRSI scores. These were incorrect or completely filled out by a large number of patients within the study and therefore not used during analysis. We have changed the way in which these are collected and hope to report on this in the future.

We caution that RTS is not necessarily the same as return to competition. We view passing a re-injury prevention test as the point at which patients can resume full sport-specific training. Selectors, coaches, and players’ fitness to play determine the actual return to competitive sport.

CONCLUSION

Patients who successfully passed an RTS test following ACLR had a 36.21% reduction in ACL re-rupture and a 19.15% reduction in contralateral ACL rupture at a mean follow-up period of 50.36 months. Younger age was a statistically significant factor in determining failure of initial RTS test and risk of contralateral ACL rupture. Sustaining a re-rupture after failing to pass an RTS test occurred significantly earlier after surgery than in those patients who re-ruptured after successfully passing an RTS test.

References


