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Reintroduction of running after ACL reconstruction with a hamstring graft: can we predict short-term success?

Return to running after ACL-R

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Study Details

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ABSTRACT

Context: Return to running (RTR) after anterior cruciate ligament reconstruction (ACL-R) is a crucial milestone. However, there is uncertainty on how and when to start a running program.

Objective: To explore the feasibility of a structured program to reintroduce running after ACL-R and to evaluate the predictive value of potential predictors of short-term success.

Design: Longitudinal cohort study.

Setting: Local Research Center / participant’s home.

Patients: Thirty-five participants were recruited after ACL-R.

Intervention: Program with a progression algorithm to reintroduce running (10 running sessions in 14 days).

Main outcome measures: The criterion for short-term success was no exacerbation of symptoms. Potential predictors included: (i) the International Knee Document Committee (IKDC) subjective knee form; (ii) ACL Return to Sport after Injury questionnaire; (iii) quadriceps and hamstring strength; (iv) Step-Down Endurance test; and (v) the modified Star Excursion Balance test. Descriptive statistics were performed to study the feasibility of the RTR program and Poisson regression analysis was used to evaluate predictors of success.

Results: Of the 34 participants included, 33 completed the RTR program. Sixteen participants experienced some temporary exacerbation of symptoms, but only one had to stop the RTR program. Initial IKDC score was the only significant predictor of a successful RTR with an Area
under the ROC curve of 80.4%. An ICKD cut-off of 63.7/100 differentiated responders and non-
responders with the highest sensitivity and specificity (77.8% and 75.0%, respectively). There
was a 3-fold greater chance of success with an IKDC score above this threshold.

**Conclusions:** Our results confirm the feasibility of our RTR program and progression algorithm
after ACL-R. Clinicians should use an IKDC score of >64 as a criterion to reintroduce running
after ACL-R to increase the likelihood of short-term success.

**Keywords:** Prediction rules, Running, Guidelines, IKDC score, ACL reconstruction

**Word counts:** Abstract 282 words; Manuscript body: 3333 words

**Key points:**

- Our program with a progression algorithm to reintroduce running after ACL-R based
  on symptom exacerbation was well tolerated by patients.

- The IKDC score was the only significant predictor of the likelihood that a patient
could return to running without short-term symptom exacerbation.
The reintroduction of running after anterior cruciate ligament reconstruction (ACL-R) is a crucial milestone for the patient and clinician. It is often considered as the first major step in the return to sport continuum. However, there are only a few studies on reintroducing running after ACL-R, leaving clinicians uncertain on how and when to start a return to running (RTR) program. Dauty et al. published two studies evaluating the feasibility of two different RTR programs after ACL-R. In these studies, the progression of the RTR programs was pre-determined and was not individualized to each participant. However, current recommendations encourage clinicians to individualize the progression of rehabilitation after ACL-R in order to optimize outcomes. In a recent scoping review by Rambaud et al., 198 of the 201 studies included reported a time-based criterion for RTR after ACL-R, starting at a median time of 12 weeks post-surgery. Only 36 studies used additional criteria to RTR, such as clinical and questionnaire evaluation, and strength and functional testing. Unfortunately, all these criteria relied solely on the opinion of experts and there was a lack of scientific validation and determination of cut-off values to help clinicians in their decision to clear a patient for a RTR program after ACL-R. A large variety of physical tests have been reported in the literature including evaluation of strength, endurance and balance, and limb symmetry. Running is a cyclical task with a series of single leg stance phases that is likely to require sufficient balance, muscular strength and endurance to tolerate knee loading. Greater recovery of these parameters may positively influence RTR. Besides the physical factors, the psychological state of the patient has been known to influence both function and recovery after ACL-R, and may predict the capacity to RTR. Questionnaires on symptoms and functional limitations evaluate a patient’s disability/ability to perform activities of daily-life and sport. It could be
meaningful to evaluate both functional limitations and psychological impact of injury before RTR.

When returning to running after ACL-R, clinicians should differentiate between short- and long-term goals. Whereas the long-term goal could be RTR performance without biomechanical alterations, a short-term goal could be to start running without exacerbation of symptoms.

In this study, we focused on the early time frame of a RTR (i.e. when to reintroduce running after ACL-R) and we considered an absence of symptom exacerbation, such as pain and knee swelling, as criteria of success. Four categories of test were evaluated: (i) questionnaire on symptom and functional limitations; (ii) questionnaire on psychological state; (iii) strength and functional endurance; and (iv) balance. The first aim of this study was to explore the feasibility of a new structured running program with a progression algorithm after ACL-R. The second aim was to evaluate the predictive values of potential predictors of short-term success of a RTR program.
METHODS

Study population

Thirty-five participants were recruited through the electronic mailing list of employees and students at our local University (Table 1). Inclusion criteria included: >18 and <60-years of age; <6 months after ACL-R; primary and unilateral ACL-R with a hamstring graft; and clearance by their physiotherapist or surgeon for a RTR. Clearance was based on time after surgery (mostly 3 or 4 months after ACL-R) and the absence of contraindications (obvious gait asymmetry, pain at rest, significant knee swelling). Participants were excluded if they had pain at rest and/or knee swelling, if they answered ‘‘Yes’’ to the question: ‘‘Have you returned to running since surgery?’’, and if they had multi-ligamentous lesions. Ethical approval for the study was granted by the ethics committees of XXXXX. Written informed consent was obtained from all participants before inclusion in the study.

Table 1. Characteristics of the Study Population at Baseline (N=35)

Study design

This longitudinal cohort study included two evaluation sessions (baseline and follow-up 14 days after baseline). At the baseline evaluation, the characteristics of the study population and data from the surgical report (e.g. meniscal and cartilage lesion) were collected. International Knee Document Committee (IKDC) subjective knee form, ACL Return to Sport after Injury (ACL-RSI) scale, and Limb Symmetry Indices (LSIs) of muscle performance (strength and functional endurance), and balance (modified Star Excursion Balance test; mSEBT) were evaluated using standardized procedures. Thereafter, during the same baseline session, all participants took part
in the first running session of their RTR program on a treadmill. The participants then performed their 2-week home-based RTR program at home without supervision. Each participant was required to fill out daily log sheets to document their compliance: date of completion, number of training sessions, and symptoms during, 1 h after and the morning after the training session. At follow-up, log-books were collected and data were checked before analysis.

Table 2. Return to Running (RTR) Program

**RTR program**

**Description of the program**

Derived from the study of Dauty et al. and guidelines suggested by Adams et al., a RTR program was developed to reintroduce running after ACL-R. This version was presented to clinical experts (n=4) on ACL rehabilitation and running-related injuries. After discussion with these experts, a consensus was reached on the final design of a structured program to reintroduce running after ACL-R with a progression algorithm based on symptom exacerbation. The program was home-based except for the first session at baseline. It included 5 running sessions a week and lasted 2 weeks. Each running session started and ended with 5 min walking, and running periods of 1 min were performed in combination with 1 min walking. The number of running periods was increased progressively and the participants were encouraged to run at their self-preferred jogging speed between 8 and 10 km/h.
A progression algorithm was designed by clinical experts based on the soreness rules of Fees et al.\(^8\) to individualize progression through the RTR program. The main guidelines were that participants could progress through the RTR program if they experienced a pain score of \(\leq 2\) on a numeric scale of 0-10 during running, and no pain 1 h after running. This was defined as ‘minimal symptoms’ and considered as acceptable to promote adaptations. In the case of more important symptoms (‘symptom exacerbation’), we considered that the load tolerance was exceeded and that it was detrimental for the recovery. If the pain was \(>2/10\) during running or if they experienced pain 1 h after running, they were asked to assess knee swelling the next morning. If participants did not detect knee swelling, they were asked to repeat the same training session. Otherwise, they rested for 1 day and stepped back one training session (Figure 1). If symptoms did not decrease when stepping back one training session after 1 day of rest, they were asked to stop the RTR program and contact the research team. A meeting between the participant, his/her physiotherapist, and a member of the research team was organized to determine the best management.

To monitor swelling, the reference above knee girth was assessed by the evaluator with a measuring tape during the baseline evaluation (mean of three measurements). Participants were instructed on how to evaluate knee joint swelling the next morning after a running session (excellent intra- and inter-tester reliability in inexperienced tester\(^9\)). A fabric strip with a length of the reference above knee girth plus 1 cm was given to the participant. If the two extremities of the fabric strip could not meet, then swelling was considered to be clinically significant.\(^9\)
Figure 1. Return to Running Progression Algorithm. Progression was based on Pain and Swelling Experienced by the Participant.

Criteria for a successful reintroduction of running

Reintroduction of running was considered to have been successful when the participant completed the RTR program (10 running sessions in 14 days) without any exacerbation of symptoms (according to the progression algorithm). This meant that symptoms remained minimal (as defined in the previous section) and that the training load did not exceed load tolerance. Participants were then classified as responders or non-responders.
Potential predictors of the successful reintroduction of running

Questionnaires

IKDC subjective knee form. The IKDC subjective knee form is a valid and reliable self-administered questionnaire that evaluates the severity of symptoms and functional limitations in patients after knee injury.\textsuperscript{10}

ACL-RSI scale. The ACL-RSI scale is a valid and reliable self-administered questionnaire evaluating psychological state in patients after ACL injury.\textsuperscript{11}

Physical tests

Isometric quadriceps and hamstring strength. Isometric quadriceps and hamstring strength was measured bilaterally using a belt-stabilized handheld dynamometer (MedUp)\textsuperscript{12,13} that was shown to be reliable (ICC: 0.98).\textsuperscript{13} Briefly, participants were seated on a table with knees flexed at 90° and grabbed the table edge with both hands. The same examiner performed this test throughout the study for all participants. The distance between the knee joint line and the point of application of the dynamometer was measured. Strength values were normalized to participant’s mass and distance of application, and expressed as Nm/kg.

Step-Down Endurance test. This procedure was described previously by Kline et al.\textsuperscript{14} In short, participants stood on a 20 cm step, performed a single limb stance, and attempted to touch a scale with the heel of their free limb without transferring more than 10% of their body weight. Participants completed as many step-downs as possible in 60 sec. Step-downs were not counted if the participants did not contact the scale, or exceeded 10% of body weight transfer, or did not fully return to the initial position. The test assesses the balance and endurance of the operated limb.\textsuperscript{14}
mSEBT. The mSEBT is a valid and reliable test used to evaluate dynamic balance. A full description of the mSEBT has been published previously. Balance was evaluated in the anterior, postero-lateral, and postero-medial planes. Directions scores were normalized to participant’s height. The composite scores (sum of the three direction scores) of the mSEBT were used as an index of dynamic balance.

Statistics

Participants who completed the RTR program with/without symptom exacerbation, or had to stop the RTR program are reported as number and percentage. The percentage of participants who experienced symptom exacerbation at the first training session, between the 2nd and 5th sessions, and between the 6th and 10th is also reported. The relationship between outcome (responder vs. non-responder) and potential predictors was determined by Poisson regression analysis. The six potential predictive factors (IKDC, ACL-RSI, Isometric-Quadriceps-LSI, Isometric-Hamstring-LSI, Endurance-LSI and mSEBT-LSI) were entered into the Poisson regression. For each predictive factor revealed by Poisson regression analysis (p<0.05), a receiver-operating characteristic (ROC) curve was computed. According to the cut-off value with the optimal sensitivity and specificity (closest point to the top left corner), the predictive continuous variable was transformed into a binary variable. Poisson regression was performed again with the binary variables (responder vs. non-responder, and below vs. above cut-off value of the predictive variable) to determine the significance of the predictive model. The relative risk (RR) was calculated if the Poisson regression analysis reached statistical significance.
RESULTS

Study population
On the 35 participants included, two withdrew from the study because of pain. The first participant experienced hamstring pain during a running session and the second participant experienced knee pain after a house move. The first participant was considered to be a non-responder and was included in the analysis; the second participant was excluded from the analysis.

Feasibility of the RTR program
Out of the 34 patients included, 18 were considered to be responders. Fifteen participants had to slow down the progression of the program because of symptoms (but still manage to perform 10 running sessions in 14 days) and one participant had to completely stop the program due to hamstring pain. The characteristics of the responders and non-responders are shown in Table 3.

Percentage of Participants who Experienced Symptom Exacerbation According to Number of Sessions of the RTR Program, and Details on Symptoms Experienced

. One participant (3%) had to stop the RTR program and 33 (97%) were able to complete the 10 running sessions. The details on symptom exacerbation are reported in Table 3, but among the 33 participants, only one reported symptom exacerbation after the first week of the program. No differences in terms of meniscal/cartilage lesion and time after surgery were reported between the responders and non-responders (Table 4).
Table 3. Percentage of Participants who Experienced Symptom Exacerbation According to Number of Sessions of the RTR Program, and Details on Symptoms Experienced

Table 4. Characteristics of Responders and Non-Responders

Evaluation of potential predictors

Poisson regression revealed that IKDC was the only predictive factor for short-term success of the RTR (p=0.0018) (Table 5). The ROC curve indicated a cut-off value of 63.7 points for the IKDC (sensitivity 77.8% and specificity 75.0%; AUC 80.4% [95%CI: 62.5-95.5]) (Figure 2).

Table 5. Results of Baseline Evaluation for Responders and Non-Responders, and Results of the Poisson Regression Analysis of Potential Predictors for a Successful Return to Running.

**p<0.01

Figure 2. ROC Curve to Discriminate Responders and Non-Responders from IKDC score. AUC with 95%CI.

Poisson regression analysis with IKDC as a continuous variable transformed into a binary variable according to the optimal cut-off value (63.7 points) reached statistical significance (p<0.001) with a RR=3.11 [95%CI: 1.29-7.53]. Participants with an IKDC score >63.7/100 had 3.11-times more chance of a successful reintroduction of running than participants with an IKDC score below this cut-off.
The aims of this study were to explore the feasibility of a structured program to reintroduce running after ACL-R and to evaluate the predictive value of potential predictors of short-term success. The most important finding is that 97% of all patients (n=33) completed 10 running sessions in 14 days. By session 5 and beyond, all but one participants were coping with our RTR program (no symptom exacerbation). Based on these results, our study confirms the feasibility of this new structured RTR program and progression algorithm to reintroduce running in patients after ACL-R.

Our results also show that there was no difference in meniscal or cartilage lesions reported at the time of surgery and time of RTR after surgery (2.8-5.4 months after ACL-R in our study) between responders and non-responders. Although meniscal and cartilage lesions may affect long-term outcomes after ACL-R,\textsuperscript{16} they do not seem to influence the short-term success of the RTR program.

According to our results, a greater IKDC score predicted the successful reintroduction of running after ACL-R. An IKDC score of >64/100 increased the chance of completing the RTR program without symptom exacerbation by 3.11. High IKDC-scores are associated with jumping performance\textsuperscript{17} and return to sport.\textsuperscript{18} A higher score may reflect a greater global capability (mix of psychological, physical and social factors) for the patient to tolerate load in daily activities, rehabilitation, and high-level functional tasks.

Another major finding of the present study is that isolated assessment of psychological impact, LSIs for strength and functional endurance, and balance do not predict the short-term success of the RTR. Ardern et al.\textsuperscript{7} demonstrated that psychological factors, such as fear of reinjury, negatively affect the return to sport after ACL-R. However, as running is an in-line activity, there
is a very limited risk of a knee sprain,\textsuperscript{19} and this could therefore explain why psychological state did not affect the short-term success of the RTR.

In terms of muscular strength, quadriceps and hamstring symmetry is essential to recover after ACL-R as it is associated with greater function,\textsuperscript{20} and a weakness of these muscles has been associated with biomechanical alterations during running after ACL-R.\textsuperscript{21} Experts recommend a minimal LSI of 60-80\% for isometric strength\textsuperscript{2} before returning to running. However, LSI is not a true measure of strength and we therefore used unilateral measures of quadriceps and hamstring strength in our study. Taken in isolation, quadriceps and hamstring strength do not seem to influence symptom exacerbation when reintroducing running after ACL-R. Moreover, there was a large variability in quadriceps and hamstring strength in our study population and complete overlap between responders and non-responders. Of note, participants were encouraged to run at their self-preferred speed, which does not require maximal activation of the quadriceps and hamstring muscles.\textsuperscript{22,23}

Among the other criteria evaluated in our study, our results show that a greater symmetry in the step-down endurance test was not related to symptom exacerbation in our RTR program. In contrast, Kline et al.\textsuperscript{14} found that a greater number of repetitions 3 months after ACL-R was predictive of better running biomechanics at 6 months after ACL-R. Biomechanical alterations and symptoms are not likely to be related and should therefore be two different aims (short- and mid-/long-term) of the RTR phase. Finally, all participants in this study had high LSI values for the mSEBT (mean: 98\%). It is possible that a ceiling effect could have affected the potential predictive value of balance. Moreover, as running is an in-line activity, multi-planar knee joint control symmetry does not seem to be meaningful to predict the short-term success of the RTR program after ACL-R.
Our study has several strengths and limitations. It adds to the body of knowledges on RTR programs, with progression based on symptom exacerbation. Our relatively small sample size could be considered a limitation. However, we focused on the homogeneity of our sample by defining specific inclusion/exclusion criteria. Principally, only participants with primary and unilateral ACL-R with a hamstring graft were recruited, and none of the patient returned to running before enrollment, increasing the internal validity of our study. Moreover, only the IKDC was strongly significant whereas the other variables were far from the significance threshold. We are therefore confident that increasing the sample size would not have significantly altered our results. A limitation of our RTR program is that it was home based and even though participants were encouraged to run at their self-preferred jogging speed between 8 and 10 km/h, we did not monitor running pace during the follow-up. Defining a successful reintroduction of running after ACL-R is challenging. Different criteria could have been chosen and would have led to different results. We could have considered biomechanical alterations as criteria of success. However, these alterations during running last for at least 5 years after ACL-R and were therefore expected when reintroducing running. As clinicians, we think that symptom exacerbation is the most meaningful way to delineate between responders and non-responders at short-term. We think that having symptoms is acceptable to promote adaptations if minimal (≤ 2/10 during running, no pain one hour after running) but may be detrimental if they are more important (> 2/10 during running, pain one hour after running, knee joint swelling). We therefore considered participants who had to slow down the running progression as non-responders.

As this study is the first one to evaluate the predictive value of potential predictors, further investigations are required to make definitive recommendations on RTR criteria.
The results of this study should help clinicians to determine how and when to reintroduce running after ACL-R. We encourage clinicians to use our RTR program after ACL-R and base progression on the algorithm developed in this study. Moreover, clinicians should be confident that patients who score >64/100 on the IKDC are likely to tolerate running loads without symptom exacerbation when reintroducing running after ACL-R. Once this 14-day RTR program is completed, clinicians are encouraged to continue the running program while respecting our progression algorithm and according to patient’s goal. We also recommend the evaluation of biomechanical alterations during running and implement targeted rehabilitation to improve long term outcomes after ACL-R.\(^{24}\)

Our results should not discourage clinicians from assessing psychological state, strength, balance and endurance through the rehabilitation process as these have implications for global outcomes after ACL-R (e.g. function, return to pre-injury sport level, risk of reinjury, knee osteoarthrosis\(^ {7,28–30}\)), and help clinicians to individualize their rehabilitation protocols.

In conclusion, this study supports the feasibility of a structured program to reintroduce running after ACL-R with a progression algorithm based on symptom exacerbation. The majority (97%) of participants were able to complete 10 running sessions in 14 days. Moreover, the results of this study showed that IKDC score was the only significant predictor of short-term success. Patients who scored >64/100 on the IKDC were 3-times more likely to tolerate the reintroduction of running without adverse reactions. Clinicians should therefore use the IKDC to individualize clinical decision-making regarding RTR after ACL-R.
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Table 1. Characteristics of the Study Population at Baseline (N=35)

| Characteristic                  | Value                          |
|---------------------------------|--------------------------------|
| Sex                             | 15 female, 20 male             |
| Age (years)                     | Mean (± SD) 28.5 ± 7.5          |
|                                 | Range (min-max) (19.4-47.5)     |
| Height (cm)                     | Mean (± SD) 173.0 ± 9.3         |
| Weight (kg)                     | Mean (± SD) 73.2 ± 13.1         |
| BMI (kg/m²)                     | Mean (± SD) 24.3 ± 2.7          |
|                                 | Range (min-max) (19.9-33.6)     |
| Pre-injury Tegner score         | Mean (± SD) 6.9 ± 1.4           |
|                                 | Range (min-max) (5-9)           |
| Time post-surgery (months)      | Mean (± SD) 3.8 ± 0.7           |
|                                 | Range (min-max) (2.8-5.4)       |

BMI: body mass index
Table 2. Return to Running (RTR) Program

| Running session | Program | Running session | Program |
|-----------------|---------|-----------------|---------|
| Week 1          |         | Week 2          |         |
| 1               | 5’W + 3*[1’R + 1’W] + 5’W | 6       | 5’W + 8*[1’R + 1’W] + 5’W |
| 2               | 5’W + 4*[1’R + 1’W] + 5’W | 7       | 5’W + 9*[1’R + 1’W] + 5’W |
| 3               | 5’W + 5*[1’R + 1’W] + 5’W | 8       | 5’W + 10*[1’R + 1’W] + 5’W |
| 4               | 5’W + 6*[1’R + 1’W] + 5’W | 9       | 5’W + 11*[1’R + 1’W] + 5’W |
| 5               | 5’W + 7*[1’R + 1’W] + 5’W | 10      | 5’W + 12*[1’R + 1’W] + 5’W |

W: walking, R: running, t: min
Table 3. Percentage of Patients who Experienced Symptom Exacerbation According to Number of Sessions of the RTR Program, and Details of Symptoms Experienced

| Symptoms                        | 1<sup>st</sup> session | 2<sup>nd</sup> to 5<sup>th</sup> session | 6<sup>th</sup> to 10<sup>th</sup> session |
|---------------------------------|------------------------|----------------------------------------|----------------------------------------|
| Patients, n (%)                 | 9/34 (26.5%)           | 6/34 (17.6%)                          | 1/34 (2.9%)                           |
| Pain >2 during running, n (mean/10) | 7 (3.1/10)            | 6 (4.7/10)                            | 1 (3.5/10)                            |
| Pain 1 h after running, n (mean/10) | 2 (2.0/10)            | 2 (2.0/10)                            | 0                                     |
| Knee swelling, n                | 0                      | 0                                      | 0                                     |
Table 4. Characteristics of Responders and Non-Responders

| Characteristics                      | Responders | Non-responders |
|--------------------------------------|------------|----------------|
| Sex (female/male), n                 | 9/9        | 6/10           |
| Age (years)                          |            |                |
| Mean (± SD)                          | 27.5 ± 8.0 | 28.9 ± 6.9     |
| Height (cm)                          |            |                |
| Mean (± SD)                          | 171.1 ± 8.0| 174.2 ± 10.3   |
| Weight (kg)                          |            |                |
| Mean (± SD)                          | 70.1 ± 10.5| 76.0 ± 15.1    |
| BMI (kg/m²)                          |            |                |
| Mean (± SD)                          | 23.8 ± 2.3 | 24.9 ± 2.9     |
| Range (min-max)                      | (20.9-33.6)| (19.9-27.6)    |
| Pre-injury Tegner score              |            |                |
| Mean (± SD)                          | 6.9 ± 1.2  | 7.0 ± 1.6      |
| Range (min-max)                      | (5-9)      | (5-9)          |
| Tegner score at baseline             |            |                |
| Mean (± SD)                          | 3.1 ± 0.8  | 3.1 ± 0.6      |
| Time post-surgery (months)           |            |                |
| Mean (± SD)                          | 3.9 ± 0.7  | 3.6 ± 0.6      |
| Range (min-max)                      | (2.8-4.4)  | (2.9-5.4)      |
| Meniscal lesions, n                  | 8          | 7              |
| Cartilage lesions, n                 | 3          | 3              |

BMI: body mass index
Table 5. Results of Baseline Evaluation of Responders and Non-Responders, Difference Between Groups, and Results of the Poisson Regression Analysis of Potential Predictors for a Successful Return to Running

|                        | Responders  | Non-Responders | P value (Poisson regression analysis) |
|------------------------|-------------|----------------|--------------------------------------|
| IKDC                   | 67.1 ± 6.7††| 59.3 ± 7.82    | 0.0014**                             |
| ACL-RSI                | 56.5 ± 19.9 | 48.8 ± 19.3    | 0.8203                               |
| Isometric quadriceps-LSI | 85.3 ± 15.9†| 82.2 ± 20.8    | 0.5960                               |
| Isometric hamstring-LSI | 66.6 ± 13.3 | 67.2 ± 16.5    | 0.5673                               |
| Step-down endurance-LSI| 94.4 ± 11.4†| 91.0 ± 28.2    | 0.9505                               |
| mSEBT-LSI              | 98.0 ± 2.2  | 97.7 ± 4.7     | 0.8001                               |

IKDC: International Knee Documentation Committee subjective knee form; ACL-RSI: Anterior Cruciate Ligament – Return to Sport after Injury; LSI: limb symmetry index; mSEBT: modified Star Excursion Balance Test.

**p<0.01, inter-group difference: †p<0.05, ††p<0.001
Figure 1. Return to Running Progression Algorithm. Progression was based on the Pain and Swelling Experienced by the Patient.
Figure 1. ROC Curve to Discriminate Responders and Non-Responders from IKDC Score. AUC with 95% CI.