THE NEW INJURIES’ RISK AFTER ACL RECONSTRUCTION MIGHT BE REDUCED WITH FUNCTIONAL TRAINING

O RISCO DE NOVAS LESÕES APÓS RECONSTRUÇÃO DO LCA PODE SER MINORADO COM O TREINAMENTO FUNCIONAL

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ABSTRACT

Objective: The objective of our study was to evaluate if functional training with the Functional Movement Screen (FMS) can reduce the risk of a new injury for patients that underwent an anterior cruciate ligament reconstruction (ACLR). Our hypothesis was that the functional training might reduce the risk of a new injury. Methods: Our training protocol consisted of six phases, each one lasting six weeks. It began two months after surgery. The study group was composed of 10 individuals that completed our protocol after ACLR. The control group consisted of 10 people that completed a regular ACLR rehabilitation protocol. The FMS was used to compare the study and control group performance. Patients with a score of 14 or less on the FMS were considered more likely to suffer an injury than those with a score higher than 14. Results: The study group average FMS score was 16.6 compared to the control group at 12.3. Functional training for ACLR rehabilitation added a statistically significant benefit (p < 0.0002) to reduce the risk of a new injury compared to regular protocol. Conclusion: Functional training may be considered an alternative to the regular ACLR rehabilitation to reduce the risk of a new injury before returning to sports.

Keywords: Knee Injuries. Ligaments. Rehabilitation.

RESUMO

Objetivo: Nosso objetivo foi avaliar se o treinamento funcional pode reduzir o risco de nova lesão, após a reconstrução do ligamento cruzado anterior (RLCA), pelo Functional Movement Screen (FMS). Nossa hipótese foi que o treinamento funcional pode diminuir o risco de nova lesão. Métodos: O treinamento consistiu em seis fases de seis semanas cada uma. Começou dois meses após a reconstrução do ligamento. O grupo estudo foi composto por 10 indivíduos que completaram o treinamento, após a RLCA. O grupo controle consistiu em 10 pessoas que fizeram o protocolo regular de reabilitação da RLCA. O FMS foi utilizado para comparar o desempenho dos dois grupos. Pacientes com pontuação igual ou inferior a 14 foram considerados mais propensos a sofrer nova lesão em comparação aqueles com pontuação maior que 14. Resultados: A pontuação média do grupo estudo foi de 16,6 e a do grupo controle, 12,3. O treinamento funcional adicionou um benefício estatisticamente significativo (p < 0,0002) para diminuir o risco de nova lesão, em comparação com o protocolo regular. Conclusão: O treinamento funcional pode ser mais uma estratégia a ser incluída na reabilitação regular da RLCA, para diminuir o risco de uma nova lesão, antes de retornar ao esporte.

Descritores: Traumatismos do Joelho. Ligamentos. Reabilitação.

INTRODUCTION

In the United States of America, approximately 90% of patients undergoing anterior cruciate ligament (ACL) injury had their ligament reconstructed.¹ After surgery, specific rehabilitation programs are used to restore joint movement, improve muscle strength and conditioning, and provide a safe return to sports participation. However, the standard anterior cruciate ligament reconstruction (ACLR) rehabilitation is not a guarantee for a return to sports at any level. The new injuries’ risk after ACL reconstruction might be reduced with functional training.
the previous activity level and for continued participation in the desired sport. 6
After an ACL injury, proprioception and neuromuscular control of
the knee are impaired, which may persist subsequently to recon-
struction and surgical rehabilitation. 7 On the other hand, inadequate
neuromuscular control may be a risk both for the first ACL injury 8,9
and for recurrent instabilities. 5
The neuromuscular training program has been used to prevent ACL
injuries in female athletes 10,11 and to avoid injuries in adolescents
and adults. 12 Risberg and Holm 13 suggested that neuromuscular
training should be part of the rehabilitation program after ACLR.
Wiggins et al., in a systematic review and meta-analysis, proposed
that neuromuscular training can help athletes under 25 to return
more safely to the sport and reduce the risk of a second injury. 12
Huang et al., 13 in a systematic review of randomized clinical trials,
reported that an ACL injury prevention program had a significant
positive effect and reduced the injury rate by 53%.
Closed kinetic chain evaluation has been used to test patients’
strength and ability to advance to a more complex functional level. 14
Functional tests, such as single leg and vertical jumping, are gen-
erally used to determine knee function after ligament reconstruc-
tion. 15,16 However, an objective and accepted method of evaluation is
needed to determine how an athlete will develop in the final
phase of rehabilitation and if he will have a safe return to sports. 17
Recently, a score ≤ 14 measured by the Functional Movement
Screen (FMS) was considered a detectable risk factor for injuries
in professional soccer players. 18 Using the FMS score, Boyle et
al. 19 found that adolescents were at increased risk for lower limb
injuries after 9 months of ACLR.
However, there is no concrete way to evaluate neuromuscular
control in individuals whose ACL was reconstructed. The objective
of our study was to evaluate if our functional training algorithm
can decrease the risk assessment of a new lesion in patients that
underwent ACLR, using the FMS scoring system.

MATERIALS AND METHODS

Informed consent was obtained from all patients participating in
the study and the study was approved by our institution’s Ethics
Committee under the number CAAE: 32800116.0.0000.5373. Inclusion criteria were considered patients that had unilateral
primary anatomic ACLR with ischiotibial tendon graft for the
management of chronic lesions and, to the exclusion, patients with
acute lesions, reconstructions with other type of graft than the
ischiotibial ones, revision or reconstruction of another ligament
associated to ACLR and patients with bilateral lesions. No patient
was a professional athlete, but all performed at least 50 hours of
sports activities per year.
Immediate total body weight support, with crutches, and full range
of motion was allowed for all patients from the first postoperative
day. No immobilization was used. The crutches were removed
after seven days, as long as there was no claudication.
After that, the patients were divided into two groups, study and control.
The study group consisted of 10 individuals that completed the pro-
posed functional training protocol after two months of physiotherapy
rehabilitation. In this group, there were eight men and two women,
aged between 25 and 53 years, with an average of 37.5 years. Regard-
ing the side, six right knees were and four left knees were treated.
The protocol consisted of a 36-week training period, starting right
after the rehabilitation period. This practice was divided in six phases
of six weeks each, and the exercises were performed three times a
week. It was based on exercises of central stability (paravertebral,
abdominal and hip musculature), correction of asymmetries in the
lower limbs and neuromuscular deficits to improve neuromuscular
control and minimize the risk of future injuries (Table 1).

| Table 1. Functional Training Protocol. |
|----------------------------------------|
| **Phase I: Week 1 to 6**               |
| **Goals:**                             |
| ➢ To restore fundamental movement patterns |
| ➢ To establish the domain of the hip and knee |
| ➢ To adequate movement patterns for physical activities |
| **Exercises:**                         |
| - Bridge: 20 sec / 8 repetitions       |
| - Board: 30 sec                       |
| - Educational squat: Medium mini-band / 3 kg medicine ball / 10 repetitions |
| - Activation of the plantar arch + lateral displacement: Medium mini-band / 4 m |
| - Educational charge: Stick / 8 repetitions |
| - Root leg activation: 10 repetitions |
| - Adduction with band: Light band / 10 repetitions |
| - Educational land survey: Baton / 10 repetitions |
| - Lunge: 3 kg medical ball / 8 reps |
| - Ankle mobility with knee flexion: 10 repetitions |
| **Phase II: Week 7 to 12**             |
| **Goals:**                             |
| ➢ To emphasize unilateral exercises |
| ➢ To minimize limb asymmetries and general deficits (strength, joint stability / mobility and neuromuscular control) |
| **Exercises:**                         |
| - TRX bridge: 20 sec / 6 repetitions |
| - Board: 30 sec                       |
| - One-sided squat: 2 kg medicine ball / 6 repetitions |
| - Unilateral rotational hip mobility with stick: 4 repetitions |
| - Unilateral educational land survey: Baton / 6 repetitions |
| - Side displacement: super band / 4m |
| - Activation of the root leg with light band / 10 repetitions |
| - Bulgarian squat: 3 kg medicine ball / 8 reps |
| - String: 30 sec                      |
| - Unilateral plyometrics: 20 cm box / 6 repetitions |
| - Pullover with ball: 6 repetitions   |
| **Phase III: Week 13 to 18**           |
| **Goals:**                             |
| ➢ To provide greater range of motion, control and perception in various positions |
| **Exercises:**                         |
| - Bridge on the ball: 20 sec / 6 repetitions |
| - Board on the ball: 30 sec            |
| - Climb in box: stick / 8 repetitions  |
| - Stick and box for hip mobility, semi-kneeling: 20 sec / 5 repetitions |
| - Deadlift: 10kg / 10 repetitions      |
| - TRX unilateral hip rotational mobility: 6 repetitions |
| - Front displacement with medium mini-band: 4 meters |
| - Unilateral Lifting with Kettlebell: 4kg / 6 repetitions |
| - Semi-Knees anti-rotation with band: 6 repetitions |
| - Side board: 20 sec                   |
| - Slide: 1 min                        |
| - Lateral attack with external rotation: stick / 6 repetitions |
| - Plyometric circuit with medium mini-band: 8 repetitions |
| - One in / low knee agility: 3 strides |
| - One in / low knee agility: 3 strides |
| - Treadmill run: 20 min / Lightweight: 50-60% of maximum heart rate |
The control group also consisted of 10 people, nine men and one woman, who underwent two months of physical therapy and a regular ACRL rehabilitation protocol, including muscle strengthening, resistance, proprioception, plyometrics and specific training, for six months. The patients were aged between 19 and 46 years, with a mean of 32.1 years. There were five right and five left knees in this group.

Both groups had comparable range of motion, joint stability and trophism of the thigh muscles. FMS was used to compare the performance of the two groups. The study group was assessed immediately after 36 weeks of functional training and the control group was assessed immediately after standard ACRL rehabilitation. The FMS analyzes the quality of seven fundamental movement patterns, applied to verify mobility, stability, neuromuscular and motor control to diagnose limitations and/or asymmetries (Figure 1).

![Goals:](Image 42x117 to 292x241)

### Goals:
- To provide the ability to generate power through a highly coordinated and efficient movement between body segments
- To maintain the ability to generate power through highly coordinated movements
- To provide conditions for training and developing specific skills

### Phase IV: Week 19 to 24
- Slide board: 20 sec / 6 repetitions
- Simultaneous squat: 5 kg / 10 repetitions
- Balance board: 45 sec
- Unilateral hip activation in the box: 20 sec
- Strong miniband lateral displacement / 4 m
- Swing Kettlebell: 10 kg / 10 repetitions
- Hip flexion and alternate knee on TRX: 10 repetitions
- Low sequential plyometrics: 5 repetitions / 30-35-40 cm
- Agility One in / high knee: 3 passes
- Agility Two in / high knee: 3 passes
- Agility Half Carica: 3 tickets
- Treadmill Run: 30 min / Light 50-60% HR Max

### Phase V: Week 25 to 30
- TRX bridge: 20 sec / 6 repetitions
- TRX unilateral board: 20 sec
- TRX unilateral onslaught: 10 reps
- Mobility rotational hip stick unstable: 5 repetitions
- Sled: 6 x 10 meters / 50 kg
- Slide board with TRX rotation: 20 sec / 4 repetitions
- Pullover Roller: 6 reps
- Olympic Weightlifting: 6 reps 5 kg / 3 reps 10 kg
- Side shift + SuperBand squat: 4 m / Medium SuperBand
- SuperBand lateral plyometrics: 4 x each side / Average SuperBand
- Agility Half Carica: 3 tickets
- Agility Slalom Jump: 3 passes
- Agility Two in Lateral: 3 passes
- Cross agility two in: 3 tickets
- Cross agility feint: 3 passes
- Educational / Running Hoplerlauf: 2 x 20
- Educational / Running Hoplerlauf Kick: 2 x 20
- Educational / Side Race Run: 2 x 20

### Phase VI: Week 31 to 36
- TRX unilateral onslaught: 10 reps
- SuperBand crouching lateral displacement: 4 m / Medium SuperBand
- Forward and reverse displacement: 6 kg / 6 repetitions
- Slide adduction: 8 repetitions / 3 kg medicine ball
- TRX Hip Flexed Side Plank: 6 reps
- Olympic Weightlifting: 10 reps / 5 kg
- TRX low pullover: 6 repetitions
- Sequential Plyometry in Total Flexion: 10 x / 40 cm
- Educational / Running
- Side run with change of direction: 3 x 30 m
- Front / back running: 3 x 30 m
- 360 ° swing race: 3 x 30 m
- Diagonal run with spin: 3 x 10 m
- Running field: 30 min / Moderate 60-75% FC Max

### Results
There was no statistically significant correlation between age, gender, side involved and FMS score. The average FMS score for the study group was 16.6, for the control group, 12.3. Tables 2 and 3 listed demographic data and FMS scores.

### Table 1. Functional Training Protocol.

| Phase IV: Week 19 to 24 | Phase V: Week 25 to 30 | Phase VI: Week 31 to 36 |
|--------------------------|------------------------|------------------------|
| **Goals:**               | **Goals:**             | **Goals:**             |
| ➢ To provide the ability to generate power through a highly coordinated and efficient movement between body segments | ➢ To maintain the ability to generate power through highly coordinated movements | ➢ To maintain the physical capabilities already acquired |
| ➢ To provide conditions for training and developing specific skills | ➢ To provide optimal conditions for training and developing specific skills without wasting energy | ➢ To provide optimal conditions for training and developing specific skills without wasting energy |

### Table 2. Age, Gender, Side and FMS Score of Study Group Patients

| Patient | Age | Gender | Side | Score |
|---------|-----|--------|------|-------|
| 1       | 27  | M      | R    | 18    |
| 2       | 43  | M      | R    | 14    |
| 3       | 37  | M      | L    | 16    |
| 4       | 32  | F      | R    | 19    |
| 5       | 53  | M      | R    | 16    |
| 6       | 34  | M      | L    | 16    |
| 7       | 25  | F      | R    | 18    |
| 8       | 42  | M      | R    | 16    |
| 9       | 45  | M      | L    | 15    |
| 10      | 37  | F      | L    | 18    |
| 37.5    |     |        |      | 16.6  |

### Figure 1. Seven tests from Functional Movement Screen.

The control group also consisted of 10 people, nine men and one woman, who underwent two months of physical therapy and a regular ACRL rehabilitation protocol, including muscle strengthening, resistance, proprioception, plyometrics and specific training, for six months. The patients were aged between 19 and 46 years, with a mean of 32.1 years. There were five right and five left knees in this group.

Both groups had comparable range of motion, joint stability and trophism of the thigh muscles. FMS was used to compare the performance of the two groups. The study group was assessed immediately after 36 weeks of functional training and the control group was assessed immediately after standard ACRL rehabilitation. The FMS analyzes the quality of seven fundamental movement patterns, applied to verify mobility, stability, neuromuscular and motor control to diagnose limitations and/or asymmetries (Figure 1).

All tests were performed by an experienced and judicious physical educator.

### Statistical analysis
The Mann-Whitney test and Fisher’s exact test were used to compare the FMS score, age, gender and affected side of the two groups. The level of significance (α) established was 0.05 or 5%.

### RESULTS
There was no statistically significant correlation between age, gender, side involved and FMS score. The average FMS score for the study group was 16.6, for the control group, 12.3. Tables 2 and 3 listed demographic data and FMS scores.
More recently, Kiapour et al., using a cadaveric landing model, proposed that knee valgus collapse is one of the main mechanisms of contactless ACL injuries in falls. With training exercises, the proposed protocol sought to work the balance between external and internal hip rotators, knee flexors and extensors and ankle invertors and evertors, to obtain dynamic knee stabilization. Thus, the dominance of the quadriceps, which could cause an increase in the ACL tension level and make it more susceptible to injuries, was corrected by dynamic neuromuscular training. The FMS score was chosen to evaluate the study and control groups, because it analyzes the whole body working together. The test helps to identify deficits in mobility, stability and neuromuscular coordination. To successfully complete the seven fundamental patterns of movement, muscle strength, flexibility, range of motion, coordination, balance and proprioception are required. Kiesel et al. suggested that a low FMS score is a proven risk factor for injuries in professional soccer players, whereas Bushman et al. considered that, although the low performance of the FMS was associated with a higher risk of injuries, it showed low sensitivity and low positive predictive value for physically active male soldiers. More recently, Bonazza et al. based on the results of a systematic review and meta-analysis, reported that the FMS has excellent inter- and intra-examiner reliability. They concluded that people with a score ≤ 14 on the FMS score are more than twice as likely to suffer a musculoskeletal injury as those with a score ≥ 14.

Our study showed that functional training after ACLR decreased the likelihood of the risk of new injuries when compared with the regular rehabilitation protocol, according to the FMS scoring system. Therefore, the suggested functional training can be a new tool to support the promotion of a safe return to sports activities after ACLR. To reduce the risk of a new ACL injury, patients should continue training at least twice a week, and a longer follow-up is mandatory. Multicenter cohort studies are needed to endorse the efficiency of the proposed protocol in preventing new ACL injuries after rehabilitation.

Our study has some limitations. The main limitation is the small number of participants in each group and the fact that this number was not based on the estimation of the sample size. Since training is demanding and time-consuming, many patients did not have the persistence to complete it. In fact, Stauberbeck et al. reported that, according to the coaches, a compliance with an injury prevention program of at least twice a week is low. The second limitation is the small number of women, two in the intervention group and one in the control group, since the incidence of ACL injuries and the risk of new injury are higher in this gender. On the other hand, our objective was to assess the new risk of new injury for patients that had ACLR using the FMS scoring system. Furthermore, in the general population, the number of men that suffer ACL injuries is greater. Another limitation was that the tests were performed by only one person, which can increase the chance of subjective influence. However, Bonazza et al. and Teyhen et al. reported that the FMS scoring system showed moderate to good inter-rater reliability, with acceptable levels of measurement error. Finally, other tests were not performed, including the one-leg jump, the vertical jump and isokinetic testing.

**CONCLUSION**

Functional training can be included in regular ACLR rehabilitation before returning to sports, with the aim of decreasing the risk of a new injury.

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**Table 3. Age, Gender, Side and FMS Score of Control Group Patients.**

| Patient | Age | Gender | Side | Score |
|---------|-----|--------|------|-------|
| 1       | 38  | M      | L    | 13    |
| 2       | 31  | M      | R    | 12    |
| 3       | 19  | M      | R    | 14    |
| 4       | 26  | M      | R    | 13    |
| 5       | 45  | M      | L    | 12    |
| 6       | 34  | M      | L    | 12    |
| 7       | 46  | F      | R    | 11    |
| 8       | 19  | M      | L    | 12    |
| 9       | 23  | M      | L    | 13    |
| 10      | 40  | M      | R    | 11    |

According to the FMS score, functional training for rehabilitation of knee with ACLR added a statistically significant benefit (p < 0.0002) to decrease the risk of further injury compared to the regular rehabilitation protocol.
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