



# Subacute Clinical Features After Arthroscopy Surgical Reconstruction of Complete Anterior Cruciate Ligament Rupture: A Case-Control Study

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## ABSTRACT

**Objective:** The purpose of this study was to describe the clinical features in the subacute phase after surgical reconstruction of complete anterior cruciate ligament rupture (ACLR) with respect to healthy participants.

**Methods:** A case-control observational study was performed. A total sample of 80 participants was recruited from an outpatient clinic and divided into case ( $n = 40$  patients after ACLR reconstruction in subacute phase) and control ( $n = 40$  healthy participants) groups. Outcomes, including pain intensity, range of motion (ROM), stability, and functionality were assessed by the visual analogue scale, universal goniometer, the Star Excursion Balance Test, and the Western Ontario and McMaster Universities Osteoarthritis Index, respectively.

**Results:** There were no statistically significant differences ( $P > .05$ ) for sex, side, age, and body mass index between patients with ACLR after reconstruction surgery and healthy participants. Statistically significant differences ( $P < .001$ ) with a large effect size (Rosenthal  $r$ ) from  $-0.86$  to  $-0.93$  were shown for ROM (median  $\pm$  interquartile range [IQR],  $-70.00^\circ \pm 10.00^\circ$ ) and Star Excursion Balance Test (mean  $\pm$  standard deviation,  $-38.31 \text{ cm} \pm 4.52 \text{ cm}$ ) reduction, as well as higher visual analogue scale (median  $\pm$  IQR,  $7.00 \pm 1.00$ ) and Western Ontario and McMaster Universities Osteoarthritis Index (median  $\pm$  IQR,  $68.77 \pm 6.29$ ) scores in favor of the ACLR reconstructed group, with respect to the healthy control group.

**Conclusions:** Measurable clinical differences of functionality, stability, and ROM should be considered during the evaluation of patients at a subacute period after complete ACLR reconstruction surgery with respect to healthy matched controls. (J Manipulative Physiol Ther 2018;41:596-601)

**Key Indexing Terms:** Anterior Cruciate Ligament; Anterior Cruciate Ligament Reconstruction; Physical Therapy Modalities; Rehabilitation

## INTRODUCTION

More than 100 000 anterior cruciate ligament ruptures (ACLR) have been reported in the United States each year. From 80 000 to 250 000 new cases of ACLR per year

occurred in the young athletic population.<sup>1</sup> The frequency of ACLR and meniscal injury may reach 0.35% and may be positively influenced by the increase of body mass index (BMI). Osteoarthritis, disability, and high sanitary costs were recognized as consequences of ACLR.<sup>2</sup> Recently,

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ACLR may commonly appear in school sports. Indeed, noncontact mechanisms seemed to be the most frequent origin of ACLR. Despite x-rays, a radiological study may rule out concomitant injuries; magnetic resonance imaging may be considered the gold standard technique to diagnose ACLR.<sup>3</sup>

The most common surgical arthroscopy method for ACLR reconstruction was the autologous graft. Among these, the bone-tendon-bone (B-T-B) technique in the central third of the patellar tendon or the hamstring tendon (H-T) technique of the semitendinosus and gracilis may be considered first-line graft methods. Benefits and complications of these autologous graft methods are deeply known.<sup>4</sup> The subacute phase after complete ACLR comprised a long resting period. Despite several interventions that were applied to accelerate the graft healing process, the clinical features and methods remain controversial during this subacute phase.<sup>5</sup>

Various physical medicine interventions have been applied after complete ACLR reconstruction. Stretching techniques, strengthening exercise, electrical current stimulation, and functional exercises have been commonly included in the rehabilitation process. Early rehabilitation does not seem to show harmful effects; however, further research should be carried out that assesses the clinical features of patients after ACLR reconstruction to establish new objectives in the rehabilitation schedule during the subacute phase.<sup>6</sup> Therefore, the main aim of this research was to describe the patients' clinical features, such as range of motion (ROM), stability, and functionality in the subacute phase after surgical reconstruction of complete ACLR with respect to healthy participants.

## METHODS

### Design

A case-control observational study was performed from February to December 2016, considering the Strengthening of Reporting of Observational Studies in Epidemiology statement.<sup>7</sup> Previously, the Interventional Ethics Research Committee (Nuestra Señora de Sonsoles Hospital, Spain, code: 11-26-2015) approval was obtained. Furthermore, the signed informed consent forms were required before the study started. The national Organic Law of Protection Data (15/1999) and the Declaration of Helsinki were considered.<sup>8</sup>

### Participants

A total of 80 participants were recruited from a Spanish outpatient clinic (patients for the case group and companions for the control group) and divided into case ( $n = 40$ ) and control ( $n = 40$ ) groups. The criteria for inclusion in the study comprised those aged between 18 and 55 years, those from subacute phase (from 1 week to 3 weeks) after unilateral reconstruction surgery of complete ACLR, and diagnosed previously by magnetic resonance imaging medical study (for the case group),<sup>9</sup> as well as healthy participants without any surgery or condition in either lower

limb (for the control group).<sup>10</sup> The criteria for exclusion in the research embraced previously diagnosed bilateral conditions in the medical record, such as L1-S4 radiculopathy, peripheral neuropathy in the lower limbs, fractures, rheumatoid diseases, prior surgical interventions in the lower extremities, complications after ACLR reconstruction surgery, current rehabilitation treatment, cognitive impairment, and prior diagnosis of at least 0.5 cm shorter length difference between both lower limbs.<sup>9,10</sup>

### Demographic and Descriptive Data

For both groups, the demographic data were sex (male or female), age (year), side (left or right knee) and BMI ( $\text{kg}/\text{m}^2$  calculated by the Quetelet's index).<sup>11</sup> For the case group, graft type (B-T-B or H-T),<sup>4-6</sup> time after surgery (days), heparin treatment,<sup>12</sup> associated conditions number, and injured structures, such as internal or external meniscus, internal or external lateral ligaments injuries, chondropathy and posterior cruciate ligament, were registered.<sup>2,9</sup>

### Outcomes

All measurements for the case group were carried out during the subacute phase (from 1 week to 3 weeks), after unilateral reconstruction surgery of complete ACLR and before the start of rehabilitation treatment. Therefore, pain intensity, ROM, stability, and functionality were assessed.<sup>9</sup>

Considering pain intensity, the visual analogue scale (VAS) of 10 cm was collected from no pain (0 cm) to the worst pain (10 cm). The VAS was shown to be a measurement tool with high reliability and validity for evaluating musculoskeletal conditions of the knee.<sup>13,14</sup>

Regarding ROM, a universal goniometer from  $0^\circ$  to  $360^\circ$  interval was used for measuring flexion mobility of the knee in prone placement (Fig 1). Indeed, the lateral epicondyle of the femoral bone coincided with the fulcrum center, and  $0^\circ$  was considered as full knee extension. This method was shown to be a reliable measurement tool for assessing participants with knee musculoskeletal injuries.<sup>14</sup>

With respect to lower limb stability, the Star Excursion Balance Test (SEBT) may be considered a reliable and valid tool for measuring dynamic postural control impairments of patients with lower extremity pathologies. A total of 5 repetitions for each 1 of the star directions was performed. The distance was measured (cm) from the star center (coinciding with the lower limb for evaluation) to the farthest point of each direction (marking with the distal extreme of the nonevaluated lower limb). The final score was performed with the 5 repetitions mean in each direction, divided by the lower limb length (multiplied by 8 directions), and multiplied by 100.<sup>15,16</sup>

With regard to knee functionality, The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was applied. This tool has demonstrated high validity and



**Fig 1.** Knee flexion measurement by means of the universal goniometer.

reliability for assessing functional features in participants after knee surgery. A total of 24 items (0-68 points) with domains, such as pain (5 items from 0-20 points), stiffness (2 items from 0-8 points), and physical function (17 items from 0-68 points) was self-reported during 5 minutes, approximately. Higher values may show a worse functionality grade.<sup>17,18</sup>

### Sample Size

Based on a prior case-control study evaluating clinical outcomes between different ACLR types, which was carried out by Ahn et al,<sup>19</sup> a convenience sample of 80 participants was considered. Therefore, 40 participants for each group were included.

### Statistical Analysis

The SPSS 23.0 statistical software (IBM Corp, Armonk, New York) was used for the statistical analysis, with a 95% confidence interval ( $\alpha$  error = 0.05), and was considered a statistically significant difference if  $P < .05$ . First, the Kolmogorov-Smirnov test was performed to evaluate normality. Frequency for qualitative variables, mean  $\pm$  standard deviation (SD) for parametric data, and median  $\pm$  interquartile range (IQR) for nonparametric data, as well as minimum and maximum values were used to describe the demographic, descriptive, and outcomes data. The Fisher's exact test was performed to analyze differences for sex and lower limb side between both groups. Considering normality distribution and variance homogeneity (Levene test), Student's  $t$  test for independent samples or  $\chi^2$  tests were utilized to assess differences for age and BMI between case

and control groups. Regarding non-normality distribution, Mann-Whitney U test completed with the effect size by means of the Rosenthal " $r$ " was performed for the outcome measurements (ROM, SEBT, WOMAC, and VAS) to compare differences between the ACLR reconstructed group and the healthy control group. Thus, Rosenthal " $r$ " was calculated by the formula  $r = \frac{Z}{\sqrt{N}}$  and interpreted as small ( $r = 0.1$ ), medium ( $r = 0.3$ ), or large ( $r = 0.5$ ) effect size for the nonparametric data.<sup>20,21</sup>

## RESULTS

### Demographic and Descriptive Data

Regarding Table 1, there were not statistically significant differences ( $P > .05$ ) for sex, side, age, and BMI between patients with ACLR after reconstruction surgery and healthy participants. Considering the case group, 20 (50%) patients with B-T-B and 20 (50%) patients with H-T graft types were recruited, illustrating a mean  $\pm$  SD of  $15.85 \pm 1.82$  days after surgery. Indeed, 23 (57.5%) patients received heparin treatment. Furthermore, a median  $\pm$  IQR of  $1.00 \pm 1.75$ , associating conditions to ACLR, was presented. Specifically, 21 (52.5%) internal and 1 (2.5%) external meniscus, 4 (10%) internal and 0 (0%) external lateral ligaments, 10 (25%) chondropathies and 1 (2.5%) posterior cruciate ligament were shown to be injured at the same time.

### Clinical Features

The clinical features differences between case and control groups are shown in Table 2. Statistically significant differences ( $P < .001$ ) with a large effect size (Rosenthal  $r$ ) from -0.86 to -0.93 were shown for ROM (median  $\pm$  IQR,

**Table 1.** Demographic and Descriptive Data Between Case (ACLR Reconstruction Surgery) and Control Groups (Healthy Participants)

| Data                   | ACLR Surgery<br>Case Group (n = 40) | Healthy Participants<br>Control Group (n = 40) | P value           |
|------------------------|-------------------------------------|------------------------------------------------|-------------------|
| Sex, male/female       | 25/15                               | 17/23                                          | .117 <sup>a</sup> |
| Side, right/left       | 21/19                               | 20/20                                          | .999 <sup>a</sup> |
| Age, y                 | 33.02 ± 8.70                        | 35.90 ± 10.12                                  | .177 <sup>b</sup> |
| BMI, kg/m <sup>2</sup> | 24.26 ± 3.55                        | 23.50 ± 3.00                                   | .301 <sup>b</sup> |

ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; SD, standard deviation.

<sup>a</sup> Frequency and Fisher's exact test were used.

<sup>b</sup> Mean ± SD and Student's *t* test for independent samples were applied.

**Table 2.** Clinical Features Between Case (ACLR Reconstruction Surgery) and Control (Healthy Participants) Groups

| Outcomes    | ACLR Surgery<br>Case Group (n = 40)          | Healthy Participants<br>Control Group (n = 40) | M-W U Test<br>P value | Effect Size<br>Rosenthal <i>r</i> |
|-------------|----------------------------------------------|------------------------------------------------|-----------------------|-----------------------------------|
| ROM, degree | 90.00 ± 10.00<br>(60.00-110.00) <sup>a</sup> | 160.00 ± 0.00<br>(150.00-160.00) <sup>a</sup>  | <.001                 | -0.92                             |
| SEBT, cm    | 58.52 ± 4.46<br>(47.62-68.34) <sup>b</sup>   | 97.10 ± 2.67<br>(91.49-99.48) <sup>a</sup>     | <.001                 | -0.86                             |
| WOMAC       | 69.45 ± 7.29<br>(59.37-76.04) <sup>a</sup>   | 0.00 ± 1.00<br>(0.00-4.00) <sup>a</sup>        | <.001                 | -0.88                             |
| VAS         | 7.00 ± 1.00<br>(5.00-8.00) <sup>a</sup>      | 0.00 ± 0.00<br>(0.00-0.00) <sup>a</sup>        | <.001                 | -0.93                             |

ACLR, anterior cruciate ligament reconstruction; IQR, interquartile range; M-W, Mann-Whitney; ROM, range of motion; SEBT, Star Excursion Balance Test; SD, standard deviation; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

<sup>a</sup> Median ± IQR (minimum-maximum) was used.

<sup>b</sup> Mean ± SD (minimum-maximum) was applied.

-70.00° ± 10.00°) and SEBT (mean ± SD, -38.31 cm ± 4.52 cm) reduction, as well as higher VAS (median ± IQR, 7.00 ± 1.00) and WOMAC (median ± IQR, 68.77 ± 6.29) scores in favor of the ACLR reconstructed group, with respect to the healthy control group.

## DISCUSSION

This study may be considered the first case-control study to describe the clinical characteristics in patients after ACLR reconstruction. Our hope is to use this information to develop new early rehabilitation purposes. Our findings show the clinical features to consider during the evaluation of patients at a subacute period after complete ACLR reconstruction surgery. The differences, with respect to the healthy control group, may be used as a clinical reference and an objective to reach the normalized values of pain intensity, functionality, stability, and range of movement.

This is the first study to compare clinical characteristics between ACLR reconstructed patients and healthy participants in a subacute phase before the start of rehabilitation. Nevertheless, prior case control studies about ACLR were focused on different aims, such as surgery types,<sup>19</sup> genetic factors,<sup>22</sup> associated bimeniscal repair,<sup>23</sup> or angiogenesis.<sup>24</sup> Thus, ACLR may be considered as a continued research focus.<sup>25</sup>

Regarding pain intensity, 7.00 ± 1.00 VAS scores indicated a pain degree between moderate and severe in this subacute phase, after ACLR surgery.<sup>13</sup> Thus, these values may be used as a clinical improvement in the return to sports participation.<sup>26</sup> Furthermore, the 33% of clinical significance and 20% of variability should be considered during the VAS assessment.<sup>13</sup>

With respect to ROM, a knee flexion reduction of -70.00° ± 10.00° was stated as a clinical difference value between both groups. Prior studies established that a difference of 15° active, non-weight-bearing ROM may be clinically important during the rehabilitation treatment of knee conditions.<sup>27</sup>

Considering functionality, a clinical difference of  $68.77 \pm 6.29$  scores in the WOMAC scale was shown between case and control groups. However, the 20% minimum clinically important difference in the WOMAC scale could be considered for knee injuries treatment between both groups.<sup>28</sup>

According to stability, a SEBT reduction of  $-38.31 \text{ cm} \pm 4.52 \text{ cm}$  may be stated as a difference of this clinical feature between ACLR reconstructed patients and healthy participants. This outcome measurement has been used as a main criterion for return to sport after ACLR reconstruction with lower reinjury risk.<sup>29</sup> In addition, the SEBT was utilized as a screening tool to evaluate dynamic postural-control deficits in participants with ACLR (range from 0.5-2 years after injury), considering all 8 directions of the SEBT, with respect to the matched limb of a healthy control group. Indeed, the anterior, lateral, posteromedial, and medial directions, showed worse dynamic postural-control stability (5%-28%). Furthermore, the noninjured extremity of the ACLR reconstructed group showed worse values than the control in the medial and lateral directions (22.8%-15.2%).<sup>15</sup>

### Limitations

Firstly, the sample size was based on a prior case-control study about ACLR reconstruction surgery.<sup>19</sup> Thus, the type II error possibility could be considered. Secondly, other recommended outcome measurements for ACLR reconstruction protocols, such laxity of the knee, International Knee Documentation Committee, Anterior Cruciate Ligament-Return to Sport After Reinjury, Tampa Scale of Kinesiophobia-11, Single Assessment Numeric Evaluation, hop tests, and isokinetic exercises have not been considered.<sup>29</sup> Third, the WOMAC Spanish validation was specifically developed for knee osteoarthritis.<sup>17,18</sup> Nevertheless, this scale has been commonly used to measure functionality with ACLR reconstructed patients.<sup>9</sup>

### CONCLUSION

In conclusion, measurable clinical differences of pain intensity, functionality, stability, and ROM should be considered during the evaluation of patients at a subacute period after complete ACLR reconstruction surgery, with respect to healthy matched controls.

### FUNDING SOURCES AND CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

### CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): C.C.-L., J.V.-S., B.R.-R.

Design (planned the methods to generate the results): C.C.-L., J.V.-S., B.R.-R.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): C.C.-L., D.R.-S., D.L.-L.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): J.V.-S. Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): C.C.-L., D.R.-S., D.L.-L.

Literature search (performed the literature search): R.F.-P., P.P.-L., J.S.-C.

Writing (responsible for writing a substantive part of the manuscript): C.C.-L., D.R.-S., D.L.-L.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): R.F.-P., P.P.-L., J.S.-C.

### Practical Applications

- The clinical features to consider during the evaluation of patients at a subacute period after complete ACLR reconstruction surgery were reported.
- The differences between healthy matched control group may be considered as a clinical reference and objective to reach the normalized values of pain intensity, functionality, stability, and range of movement.
- This is the first study to compare clinical characteristics between ACLR reconstructed patients and healthy matched controls before the start of rehabilitation.

### REFERENCES

1. Mall NA, Chalmers PN, Moric M, et al. Incidence and trends of anterior cruciate ligament reconstruction in the United States. *Am J Sports Med.* 2014;42(10):2363-2370.
2. Thein R, Hershkovich O, Gordon B, et al. The prevalence of cruciate ligament and meniscus knee injury in young adults and associations with gender, body mass index, and height a large cross-sectional study. *J Knee Surg.* 2017;30(6):565-570.
3. Kaeding CC, Léger-St-Jean B, Magnussen RA. Epidemiology and diagnosis of anterior cruciate ligament injuries. *Clin Sports Med.* 2017;36(1):1-8.
4. Liechti DJ, Chahla J, Dean CS, et al. Outcomes and risk factors of rerevision anterior cruciate ligament reconstruction: a systematic review. *Arthroscopy.* 2016;32(10):2151-2159.
5. Valentí Azcárate A, Lamo-Espinosa J, Aquerreta Beola JD, Hernandez Gonzalez M, Mora Gasque G, Valentí Nin JR. Comparison between two different platelet-rich plasma

- preparations and control applied during anterior cruciate ligament reconstruction. Is there any evidence to support their use? *Injury*. 2014;45(suppl 4):S36-S41.
6. Kruse LM, Gray B, Wright RW. Rehabilitation after anterior cruciate ligament reconstruction. *J Bone Joint Surg Am*. 2012; 94(19):1737-1748.
7. Vandembroucke JP, von Elm E, Altman DG, et al. Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. *Int J Surg*. 2014;12(12):1500-1524.
8. Holt GR. Declaration of Helsinki-The world's document of conscience and responsibility. *South Med J*. 2014;107(7):407.
9. Velázquez-Saomil J, Ruiz-Ruiz B, Rodríguez-Sanz D, Romero-Morales C, López-López D, Calvo-Lobo C. Efficacy of quadriceps vastus medialis dry needling in a rehabilitation protocol after surgical reconstruction of complete anterior cruciate ligament rupture. *Medicine (Baltimore)*. 2017;96(17):e6726.
10. Larson CM, Bedi A, Dietrich ME, et al. Generalized hypermobility, knee hyperextension, and outcomes after anterior cruciate ligament reconstruction: prospective, case-control study with mean 6 years follow-up. *Arthroscopy*. 2017;33(10):1852-1858.
11. Garrow JS. Quetelet index as indicator of obesity. *Lancet (London, England)*. 1986;1(8488):1219.
12. Leong NL, Arshi A, Kabir N, et al. In vitro and in vivo evaluation of heparin mediated growth factor release from tissue-engineered constructs for anterior cruciate ligament reconstruction. *J Orthop Res*. 2015;33(2):229-236.
13. Williamson A, Hoggart B. Pain: a review of three commonly used pain rating scales. *J Clin Nurs*. 2005;14(7):798-804.
14. Howe TE, Dawson LJ, Syme G, Duncan L, Reid J. Evaluation of outcome measures for use in clinical practice for adults with musculoskeletal conditions of the knee: a systematic review. *Man Ther*. 2012;17(2):100-118.
15. Gribble PA, Hertel J, Plisky P. Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train*. 2012;47(3):339-357.
16. Gribble PA, Kelly SE, Refshauge KM, Hiller CE. Interrater reliability of the star excursion balance test. *J Athl Train*. 2013;48(5):621-626.
17. Escobar A, Quintana JM, Bilbao A, Azkárte J, Güenaga JJ. Validation of the Spanish version of the WOMAC questionnaire for patients with hip or knee osteoarthritis. *Clin Rheumatol*. 2002;21(6):466-471.
18. Jinks C, Jordan K, Croft P. Measuring the population impact of knee pain and disability with the Western Ontario and McMaster Universities osteoarthritis index (WOMAC). *Pain*. 2002;100(1-2):55-64.
19. Ahn JH, Lee YS, Jeong HJ, et al. Comparison of transtibial and retrograde outside-in techniques of anterior cruciate ligament reconstruction in terms of graft nature and clinical outcomes: a case control study using 3T MRI. *Arch Orthop Trauma Surg*. 2017;137(3):357-365.
20. Field A. *Discovering Statistics Using SPSS: (and Sex, Drugs and Rock "N" Roll)*. London, UK: Sage Publications; 2005.
21. Rosenthal R. *Meta-analytic Procedures for Social Research*. Newbury Park, CA: Sage; 1991.
22. Cieszczyk P, Willard K, Gronek P, et al. Are genes encoding proteoglycans really associated with the risk of anterior cruciate ligament rupture? *Biol Sport*. 2017;34(2):97-103.
23. Gonçalves H, Steltzlen C, Boisrenoult P, Beaufils P, Pujol N. High failure rate of anterior cruciate ligament reconstruction with bimeniscal repair: a case-control study. *Orthop Traumatol Surg Res*. 2017;103(6):943-946.
24. Rahim M, Hobbs H, van der Merwe W, Posthumus M, Collins M, September AV. Investigation of angiogenesis genes with anterior cruciate ligament rupture risk in a South African population. *J Sports Sci*. 2018;36(5):551-557.
25. Simoneau GG. 2015 JOSPT Awards: Back pain and anterior cruciate ligament injuries are a continued focus of research and clinical attention in physical therapy. *J Orthop Sports Phys Ther*. 2016;46(4):230-231.
26. Lentz TA, Zeppieri G, Tillman SM, et al. Return to preinjury sports participation following anterior cruciate ligament reconstruction: contributions of demographic, knee impairment, and self-report measures. *J Orthop Sports Phys Ther*. 2012;42(11):893-901.
27. Aigner C, Windhager R, Pechmann M, Rehak P, Engeleke K. The influence of an anterior-posterior gliding mobile bearing on range of motion after total knee arthroplasty. A prospective, randomized, double-blinded study. *J Bone Joint Surg Am*. 2004;86-A(10):2257-2262.
28. Raynauld JP, Torrance GW, Band PA, et al. A prospective, randomized, pragmatic, health outcomes trial evaluating the incorporation of hylan G-F 20 into the treatment paradigm for patients with knee osteoarthritis (Part 1 of 2): clinical results. *Osteoarthritis Cartil*. 2002;10(7):506-517.
29. Rambaud AJM, Semay B, Samozino P, et al. Criteria for Return to Sport after Anterior Cruciate Ligament reconstruction with lower reinjury risk (CR'STAL study): protocol for a prospective observational study in France. *BMJ Open*. 2017;7(6):e015087.