

# The anterior cruciate ligament (ACL) reconstruction in athletes and non-athletes: single- or double-bundle; review

*La reconstrucción del ligamento cruzado anterior (LCA) en atletas y no atletas: un solo paquete o doble paquete; revisión*

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## Abstract

**Background:** The anterior cruciate ligament (ACL) consists of two functional bundles, the anteromedial bundle, and the posterolateral bundle. Furthermore, these bundles work synergistically to provide knee anteroposterior and rotational stability. ACL injury causes reduce the function, balance, and destruction of the knee joint. This review was performed to describe current information on anterior cruciate ligament reconstruction and its effect on activities of athletes and non-athletes as well as express the difference between "single-bundle" and "double-bundle".

**Methods:** Different databases were checked and analyzed to write this review.

**Results:** Anterior cruciate ligament injury is common among athletes and even non-athletes. Because of the prevalence of ACL rupture, the reconstruction of the anterior cruciate ligament is one of the most frequently performed orthopedic surgeries. Reconstruction of the anterior cruciate ligament has evolved significantly over the past 40 years. Reconstruction of ACL in the double-bundle technique is advocated more closely restore the function of the native ligament than the conventional single-bundle technique. Previous research has shown that double-bundle anterior cruciate ligament replacement has a considerable advantage in anterior and rotational stability when compared to single-bundle anterior cruciate ligament restoration. However, because to the difficulty of the double-bundle, most surgeons consider the single-bundle to be the preferable method of ACL reconstruction.

**Conclusion:** ACL Injuries in athletes were extensively studied, however many ACL lesions are seen in non-athletes as a result of low-grade recreational activities which is not well addressed. Because performing the appropriate method of the anterior cruciate ligament reconstruction will be related to the continuation of activities and the life quality of individuals.

**Key words:** ACL reconstruction, athletes, single-bundle, double-bundle.

## Resumen

**Antecedentes:** El ligamento cruzado anterior (LCA) consta de dos haces funcionales, el haz anteromedial y el haz posterolateral. Además, estos haces trabajan de forma sinérgica para proporcionar estabilidad anteroposterior y rotacional a la rodilla. Las lesiones del LCA reducen la función, el equilibrio y la destrucción de la articulación de la rodilla. Esta revisión se realizó para describir la información actual sobre la reconstrucción del ligamento cruzado anterior y su efecto en las actividades de los atletas y los no atletas, así como para expresar la diferencia entre el "haz simple" y el "haz doble".

**Métodos:** Se revisaron y analizaron diferentes bases de datos para redactar esta revisión.

**Resultados:** La lesión del ligamento cruzado anterior es común entre los atletas e incluso entre los no atletas. Debido a la prevalencia de la rotura del LCA, la reconstrucción del ligamento cruzado anterior es una de las cirugías ortopédicas más frecuentes. La reconstrucción del ligamento cruzado anterior ha evolucionado considerablemente en los últimos 40 años. Se defiende que la reconstrucción del LCA con la técnica de doble haz restablece más estrechamente la función del ligamento nativo que la técnica convencional de un solo haz. Investigaciones anteriores han demostrado que la sustitución del ligamento cruzado anterior con doble haz tiene una ventaja considerable en cuanto a la estabilidad anterior y rotacional en comparación con la restauración del ligamento cruzado anterior con un solo haz. Sin embargo, debido a la dificultad del doble haz, la mayoría de los cirujanos consideran que el haz único es el método preferible para la reconstrucción del LCA.

**Conclusión:** Las lesiones del LCA en los atletas fueron ampliamente estudiadas, sin embargo, muchas lesiones del LCA se ven en los no atletas como resultado de actividades recreativas de bajo grado que no se aborda bien. Porque realizar el método adecuado de la reconstrucción del ligamento cruzado anterior estará relacionado con la continuación de las actividades y la calidad de vida de los individuos.

**Palabras clave:** Reconstrucción del LCA, deportistas, ligamento simple, ligamento doble.

## Introduction

One of the most important knee stabilizing ligaments is the anterior cruciate ligament<sup>1</sup>. The anterior cruciate ligament (ACL) helps maintain dynamic-static stability and knee joint coordination. ACL injury has a severe effect on knee mobility and balance<sup>2</sup>. This injury causes effective sensory feedback in the injured knee which can reduce the function and balance of knee joint<sup>3</sup>. Among the joint injuries associated with sports movements, the knee accounts for about 10-25 % of all injuries, and among knee injuries, about 45% are related to ligament injuries<sup>4</sup>. ACL injury is common among athletes and even non-athletes, to the extent that one in 3,000 people in the United States suffers from ACL injury annually<sup>5</sup>. ACL injury, is one of the most devastating orthopedic diseases, which can result in a lot of time lost from sport<sup>6</sup>.

Because of the prevalence of ACL injuries, ACL reconstruction is one of the most frequently performed orthopedic surgeries<sup>7,8</sup>. Surgical procedures conducted to reconstruct ACL are usually “single-bundled” or “double-bundled”. In general, anterior cruciate ligament reconstruction using the appropriate method was associated with the continuation of activities and the life quality of patients.

Therefore, our goals in this paper are to provide a brief overview of describe current information on anterior cruciate ligament reconstruction and its effect on activities of athletes and non-athletes, as well as express the difference between “single bundle” and “double bundle” technique. We performed the literature review within the PubMed database using the keywords: “ACL Reconstruction, Athletes, Single-Bundle, Double-Bundle” with dates from 2000 to 2021. This paper describes the complications of anterior cruciate ligament injuries and provides an overview of the ACL reconstruction technique. We then present a review on the reconstruction of ACL in athletes and non-athletes as well as a comparison of the single-bundled and double-bundled as surgical procedures performed to reconstruct the ACL.

### ACL injuries

ACL is one of the most important elements to stabilize the knee and is vital for the stability of the knee joint during running and sports activities. ACL consists of two major functional bundles, the smaller anteromedial (AM) and the larger posterolateral (PL) bundle. When the knee is extended, the PL bundle is tight, and the AM bundle is quite lax. As the knee is flexed, the AM bundle is tight, and the PL bundle is relax (Figure 1&2). With the knee flexed the AM bundle is the primary resistance against the anterior translation of the tibia, while the bulky PL bundle tends to stabilize the knee near full extension, particularly against rotation<sup>9,10</sup>.

ACL injuries are among the most frequent knee ligament

injuries in the world with an incidence of 8 per 100,000 cases per year<sup>11-15</sup>. The most affected are between 15 and 25 years old and athletes.

Regarding the low average of age in the Iranian population, the frequency of ACL tear is high, but there is no accurate estimate of this injury in Iran<sup>16</sup>. In the United States, about 200,000 ACL tear occurs per year<sup>17-20</sup>. Tears of this ligament are linked to knee instability and other ligament injuries. Long-term effects from ACL injury include meniscus tears and articular cartilage degradation. As a result, in the majority of cases, ACL rupture necessitates ligament reconstruction surgery. Because of the operation and subsequent complications, the athlete must take at least six months off from their major sports activity.

Figure 1: Anterior cruciate ligament injury.

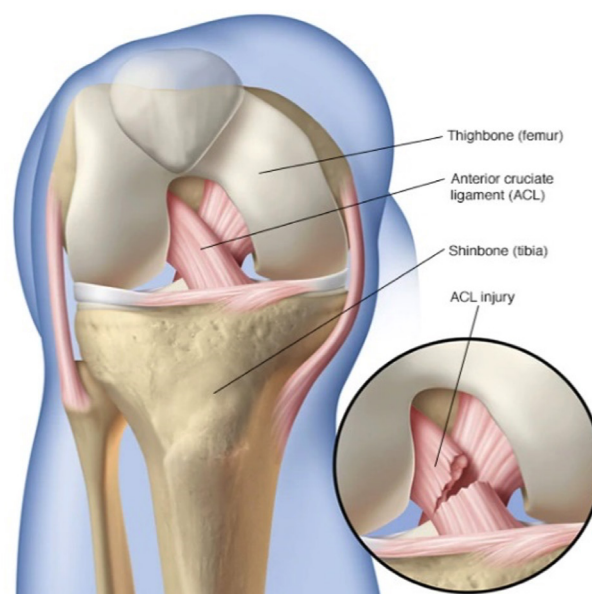
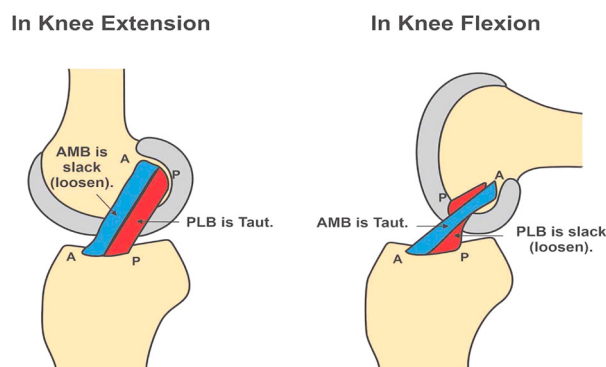


Figure 2: AM and PL bundles of Acl in extension and flexion\*.



\* Retrieved from: <https://physio-study.com/anterior-cruciate-ligament-anatomy-biomechanics/#more-2031>

## ACL reconstruction

ACL reconstruction has significantly evolved over the past 40 years with debate regarding the timing of reconstruction<sup>18</sup>. The surgery method is the common treatment for athletes because it restores stability and limits the potential for progressive degeneration and instability of the knee.

Early surgery may facilitate back to work or sporting; conversely, delayed reconstruction of ACL can be associated with delayed early rehabilitation due to increased muscle atrophy and reduced strength<sup>21</sup>. There is no consensus on the optimal time to perform ACL reconstruction surgery<sup>22</sup>. Early studies have recommended that early reconstruction may facilitate an early return to work but may increase the incidence of post-operative complications<sup>23</sup>. Smith et al., (2010) in a study entitled 'Early versus delayed surgery for ACL reconstruction: a systematic review and meta-analysis' based on the current literature found there was no difference in clinical outcome among the patients who underwent early compared with delayed ACL reconstruction<sup>22</sup>. Although in a survey of 101 consultant orthopedic surgeons, 81% reported that they considered the ideal time span from injury to operation to be between 1 and 6 months<sup>24</sup>. Probably early surgical intervention during the initial weeks post-injury resulted in restoring tibiofemoral stability that can minimize the risk of further meniscal injury which may be associated with degenerative joint changes<sup>25</sup>. On the other hand, some research suggest that delaying surgical intervention potentially reduce the incidence of post-operative arthrofibrosis in terms of the optimization of pre-operative knee range of motion and recovery of surrounding soft tissues from the initial injury<sup>26</sup>.

## ACL reconstruction in athletes and non-athletes

Previous studies showed that physical activity is the most common risk factor for ACL injuries in young people. Today, public health guidance programs strongly recommend regular physical activity to improve health and reduce the risk of chronic disease. Therefore, the number of athletes is rapidly increasing<sup>27</sup>. As a result, the risk of ACL injury is increased, and such injuries now involve significant amounts of public health costs<sup>28</sup>. A descriptive study of communities can identify people at risk in society, identify harmful situations and mechanisms, and help intervention programs to mitigate these harms. It is demonstrated that ACL injuries are one of the most frequent types of sports injury<sup>29</sup>. Although the need for reconstruction of ACL in athletes is explicit; however, there are some differences of opinion on managing ACL injuries in non-athlete persons<sup>30</sup>. Injuries of the ACL in athletes were studied extensively in orthopedic sports medicine, however many ACL lesions are seen in non-athletes as a result of accidents or low-grade recreational activities, which is not well addressed<sup>31</sup>.

Reconstruction of ACL is readily offered to athletes, whereas this treatment is sometimes conservatively for non-athletes<sup>32,33</sup>. The treatment of injuries of the ACL in athletes was widely performed. But, the outcome of non-operative management in the general population was neglected.

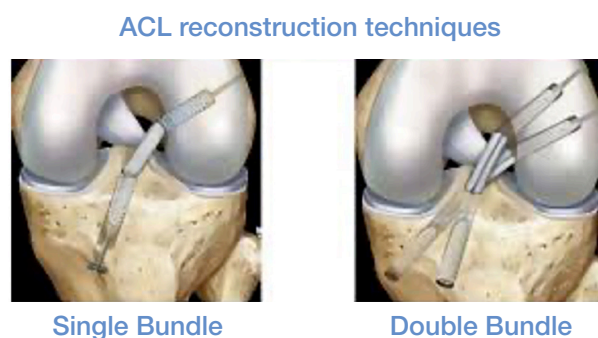
Many ACL injuries in non-athletes may be lost in terms of the conservative management, assuming that non-athletes do not have a significant degree of instability. In fact, there may be a high rate of instability and meniscus injuries in non-athletes.

## Double-bundle versus single-bundle

Early reports of ACL reconstruction were first published 30 years ago<sup>34</sup>. Surgical procedures performed to reconstruct the ACL are usually "single-bundled" or "double-bundled"<sup>35</sup>. The single-bundled is widely accepted as the standard surgical option to reconstruct ACL injuries. The single bundled is effective in restoring anterior stability and has favorable postoperative clinical results. However, several studies have linked the single-bundled method to an increased risk of osteoarthritis and rotational instability problems. The focus of advances in ACL reconstructive techniques is to reduce these complications. Therefore, double blinded ACL reconstruction is considered by many surgeons as an attractive option<sup>34</sup>.

The technique of replicating the complex anatomy of ACL in a double-bundle technique was first described in 1983<sup>36</sup>. Then, many technical variations of the procedure were added in recent decades (**Figure 3**).

**Figure 3:** Single vs. double bundle technique<sup>38</sup>.



However, the literature review showed that most of the methods of ACL reconstruction focused on using a single bundle so that various single-bundle techniques have still dominated during the past years. Although this technique has high success rates but 30% of patients experience persistent knee pain or instability<sup>37</sup>.

Double bundle and single bundle techniques could be compared from various aspects. Different studies have evaluated the return to the preinjury level according to the

Lysholm score, the functionality of the knee according to Subjective International Knee Documentation Committee (IKDC) score, active reincorporation, anteroposterior and rotational stability, development of osteoarthritis, and graft rupture.

Anterior and rotational stability in ACL reconstruction is very important as it may be correlated with the risk of meniscus and cartilage injury, as well as graft rupture and osteoarthritis changes<sup>39</sup>. Some research showed that single-bundle and double bundle surgery provide anterior stability as these two techniques could closely imitate AMB in ACL reconstruction, and there is no significant difference between these two techniques in this regard<sup>40</sup>. However, there are some concerns regarding the failure of single bundle technique to provide adequate rotational stability in the knee<sup>41</sup>. To improve rotational stability, surgical procedures in “double bundles” were modified to reconstruct not only the anteromedial bundle but also the posterolateral bundle<sup>42</sup>. Therefore, the reconstruction of ACL using Double-bundle method was developed to reconstruct both the anteromedial and posterolateral bundles. Theoretically, the double bundle technique reconstructed PLB, in addition to AMB, which functions at extension and contributed more to rotational stability. Some studies have revealed improving in rotational stability for double-bundle reconstruction compared with single-bundle<sup>43</sup>, and Biomechanical studies show a significant advantage in anterior and rotational stability with double-bundle compared to single-bundle ACL reconstruction<sup>36</sup>. The concept behind this result is that rotational stability increase significantly with the additional reconstruction of the PLB when compared to a single bundle ACL reconstruction<sup>35</sup>. However, more recent systematic reviews and meta-analysis show that there was no significant difference between the double-bundle and single-bundle techniques in rotational stability<sup>40</sup>. An explanation for this result is that perhaps the other peripheral structures, such as the collateral ligaments and the muscles that cross the joint play an important role in rotational stability<sup>44</sup>.

In more recent systematic review and meta-analysis study, with a total of 1707 patients, the qualitative and quantitative analysis showed that there is no clear difference between these two techniques in knee function or sports incorporation and the true difference is in the subjective assessment by the patient and not the objective assessment<sup>45</sup>. The higher subjective feeling of the patient in the double-bundle technique allows the patient greater confidence in their return to physical activities. Therefore, the evaluation of the patient and activity levels should be considered when choosing the double-bundle technique.

Graft failure is another factor to consider to compare double-bundle and single-bundle techniques. It increases the individual suffering, recurrent instability, and future

economic burden<sup>46</sup>. A meta-analysis conducted in 2018 showed that double-bundle technique has no advantage over single bundle regarding graft failure rate. The latter is mostly affected by other factors including new knee trauma, infection of implanted graft, returning too soon to pivoting sports, and radical rehabilitation programs rather than the technique<sup>47</sup>.

Regarding osteoarthritis changes, again most recent meta-analysis did not show any statistically significant difference between double-bundle and single-bundle technique. Theoretically, single-bundle might result in a smaller patellofemoral and tibiofemoral contact area and greater pressures and subsequent osteoarthritis changes<sup>48</sup>. However, delay from the primary injury to ACL reconstruction, concomitant injury, such as meniscal or another ligament tear, influence osteoarthritis changes more than the single or double technique<sup>43,49</sup>.

In conclusion, it seems that double-bundle technique has no significant superiority over single bundle. In one hand, double-bundle seems to be associated with better subjective functionality; on the other hand, probably because of the complexity of the double-bundle, still the single-bundle is considered the preferred choice for most of surgeons for ACL reconstruction<sup>50</sup>. Some of the studies on the superiority of these reconstruction techniques over each other have a follow-up period less than three to five years, a follow-up period that is too short to observe the natural history of the injured ACL repair and the postoperative changes to the knee and this may be a reason for the existed controversy.

## Conclusion

Because of the prevalence of anterior cruciate ligament tears, ACL reconstruction is one of the most frequently performed orthopedic surgeries. Anterior cruciate ligament damage is widespread in both athletes and non-athletes, and it is poorly treated. Some clinical data revealed that “double-bundle” surgery provided greater anterior-posterior and rotational stability than “single-bundle” surgery. Other studies have shown no significant difference between a “single-bundle” and a “double-bundle.” Probably because of the complexity of the double-bundle, the single-bundle considered the preferred choice for most of the surgeons for ACL reconstruction. Although it seems that this choice may have more anatomical and biomechanical reasons related to the complexity of the surgical procedure.

## Conflict of Interest

The authors declare that there is no conflict of interest in the publication of this paper.

Table 1: Studies on anterior cruciate ligament reconstruction.

First Author (year)	Title	Aim	Conclusion	Ref
<b>Maestro (2021)</b>	Subjective assessment reported by the patients shows differences between single-bundle and double-bundle anterior cruciate ligament reconstruction, systematic review and meta-analysis	To compare the functional recovery, active reincorporation, and anteroposterior and rotational stability of patients undergoing ACL reconstruction using techniques of simple-bundle or double-bundle	There is no clear or significant difference in the clinical stability and knee function or in sports incorporation	45
<b>Chen (2020)</b>	Single-bundle versus double-bundle autologous anterior cruciate ligament reconstruction: a meta-analysis of randomized controlled trials at 5-year minimum follow-up	Compare the mid- to long-term outcome of single bundle and double bundle ACL reconstruction concerning knee stability, clinical function, graft failure rate, and osteoarthritis (OA) changes.	The double bundle was not superior to the single bundle in ACL reconstruction regarding knee stability, clinical function, graft failure rate, and OA changes with a mid- to long-term follow-up	40
<b>Dong (2019)</b>	Long-term results after double and single bundle ACL reconstruction: Is there any difference? A meta - analysis of randomized controlled trials	Compare the longer-term efficacy between double-bundle and single-bundle techniques.	Single-bundle and double-bundle techniques could yield similar efficacy. No superiority was founded in double bundle ACL reconstruction with a minimal 5-year follow-up	44
<b>Chowdhury (2019)</b>	Anterior Cruciate Ligament Reconstruction Using Autologous Hamstring Double Bundle Graft Compared with Single Bundle Graft Procedures	Comparing the clinical and functional outcome of autologous double bundle and single bundle reconstruction for ACL injury.	Compared to single bundle the post-operative symptoms and signs were more improved in double bundle. Rotational and anterior stability of the knee was better in the double bundle group although not significant and all patients in our study were able to return their activity.	51
<b>Grassi (2018)</b>	New Trends in Anterior Cruciate Ligament Reconstruction: A Systematic Review...	Analyzing national surveys of orthopedic surgeons on ACL reconstruction to determine their preferences related to the preferred graft	Single-bundle reconstruction with anteromedial portal technique and suspension femoral fixation and screws fixation for the tibia seem the preferred solution.	52
<b>Kay (2018)</b>	Over 90 % of children and adolescents return to sport after anterior cruciate ligament reconstruction...	Evaluating the rate at which children and adolescent athletes return to sporting activities after ACL reconstruction	There is a high rate of return to sport following ACL reconstruction in children and adolescent. However, this is associated with a relatively high rate of graft tears and a similar rate of contralateral ACL injury.	53
<b>Jarvela (2017)</b>	Double-Bundle Versus Single-Bundle Anterior Cruciate Ligament Reconstruction.	Evaluating the rate of graft failure, knee stability and OA in double bundle and single bundle ACL reconstruction at 10-year follow-up	Double-bundle resulted in significantly fewer graft failures than single-bundle. Knee stability and OA rates were similar.	54
<b>Devgan (2016)</b>	A prospective study to evaluate the clinico-radiological outcomes of arthroscopic single bundle versus double bundle anterior cruciate ligament reconstruction	Compare clinical and radiological outcomes of arthroscopic single-bundle versus double-bundle ACL reconstruction	No statistically significant difference in knee stability, knee scores, subjective evaluations, and MRI evaluation between single- and double-bundle ACL reconstruction	55
<b>Grassi (2016)</b>	Returning to sport after ACL reconstruction: a survey between the Italian Society of Knee...	To survey among Italian Society of Knee, Arthroscopy, Sport, Cartilage and Orthopedic Technologies members in order to evaluate their approaches to the return to sport after ACL reconstruction	Six months was generally considered adequate by most of the members for the most demanding activities. The most used criteria to allow return to sport were manual testing.	56
<b>Ambra (2016)</b>	Anterior cruciate ligament reconstruction: how do we perform it? ...	Evaluating the current trends and common practice of Brazilian orthopedic surgeons, while selecting approaches for ACL reconstruction surgery.	Surgeons' preferences for ACL reconstruction are variable, and are influenced by learning time and availability of tools rather than research evidence.	57
<b>Middleton (2014)</b>	Anatomic anterior cruciate ligament reconstruction: a global perspective	To discuss current concepts, approaches, and techniques in the field of ACL reconstruction among leading surgeons in the field.	The most popular graft choice is hamstring tendon autograft. Nearly half of the surgeons surveyed performed both single- and double-bundle ACL reconstructions depending on certain criteria.	14
<b>Smith (2010)</b>	Early versus delayed surgery for ACL reconstruction: a systematic review and meta-analysis	To determine whether ACL reconstruction should be performed acutely following tears.	There was no difference in clinical outcome between patients who underwent early compared to delayed ACL reconstruction.	22
<b>Carola (2009)</b>	Anatomic Single- and Double-Bundle ACL Reconstruction Flowchart	To define anatomic ACL reconstruction as the functional restoration of the ACL to its native dimensions, collagen orientation, and insertion sites.	A flowchart was developed that can help orthopedic surgeons perform anatomic ACL reconstruction. This flowchart is applicable to both single- and double-bundle reconstruction and is accompanied by informative tables, figures, videos, and valuable literature	58

First Author (year)	Title	Aim	Conclusion	Ref
Joseph (2008)	Is ACL reconstruction only for athletes?	To compare the incidence of meniscal and cartilage injuries in an athlete and non-athlete population in relation to time of presentation since injury	Both athletes and non-athletes are equally susceptible for long-term meniscal and cartilage injuries if ACL reconstruction is not carried out early.	29
Siebold (2008)	Prospective Randomized Comparison of Double-Bundle Versus Single-Bundle ACL Reconstruction	To evaluate the clinical results of four-tunnel Double-Bundle ACL reconstruction	The results show a significant advantage in the anterior and rotational stability for Double-Bundle ACL reconstruction compared to Single-Bundle ACL reconstruction	36
Jarvela (2007)	Double-bundle versus single-bundle ACL reconstruction...	To compare the outcomes of ACL reconstruction when using either double-bundle or single-bundle technique	The rotational stability was significantly better in the double-bundle group than in the single-bundle group. In anterior stability of the knee, there was no significant difference between the groups.	34
Drosos (2004)	The causes and mechanisms of meniscal injuries in the sporting and non-sporting environment ...	To establish the etiology and circumstances of meniscal injuries in the general adult population	In an unselected general adult population nearly one third of meniscal injuries occur in the course of non-sporting activities of daily living and one third in the absence of any recognized injury.	33

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