

# Current evidence around patellar tendon graft in ACLR for high-risk patients: current concepts

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## ABSTRACT

Hamstrings and patellar tendon (PT) are the most common autografts used to perform anterior cruciate ligament (ACL) reconstructions. The debate to know which graft should be better has been going on for decades. However, in relation to underpowered studies, no strong conclusions have been drawn until recently. Indeed, there was a need for a greater magnitude of data and assessment of specific population to properly compare these grafts. Our objective was to provide a current review based on recent scientific publications with high level of evidence. Registries have provided conclusive information. The **Scandinavian** registry showed lower failure rate for bone–patellar tendon–bone (BPTB) versus hamstring tendon (HT) at 5-year follow-up in over 45 000 patients (2.8% vs 4.2%;  $p < 0.001$ ). In the Norwegian registry, with 12 643 patients included, higher revision rates were recorded in HT graft versus BPTB graft at all follow-up times (2.8% vs 0.7% at 2 years and 5.1% vs 2.1% at 5 years). Moreover, as far as high-risk profile patients were concerned, this difference was even more significant. This trend has also been confirmed more recently in a study when assessing **young females**, showing that the failure rate amounted to 6.4% in the PT group while it reached 17.5% in the HT group at 3.7-year follow-up ( $p = 0.02$ ). ACL graft selection should be a discussion between the physician and the patient, taking into consideration age, activity level and occupation. Within the high-risk patient group however, scientific evidence supports the PT as the gold standard for ACL reconstruction.

## INTRODUCTION

When it comes to choosing the right graft for an anterior cruciate ligament reconstruction (ACLR), numerous criteria require consideration. The ideal graft does not exist, but there is room for discussion around the topic. The most important factor is failure rate, but other criteria such as contralateral anterior cruciate ligament (ACL) rupture, return to sport rate, complications, functional outcomes, meniscal tears or postoperative pain should be taken into account. The two most popular grafts are bone–patellar tendon–bone (BPTB) and hamstring tendon (HT).

Potential drawbacks of a BPTB autograft include the risk of anterior knee pain, patellar fracture, patellar tendon (PT) rupture, quadriceps weakness and donor site morbidity, while the disadvantages of an HT autograft include hamstring pain, decreased hamstring strength, increased joint laxity and delayed graft-tunnel healing with more tunnel enlargement. HT is the most used graft in New

## Current concepts

- ▶ There is increasing scientific evidence that patellar tendon has lower failure rate than hamstring autograft in anterior cruciate ligament reconstruction.
- ▶ This difference is greater in high-risk profile patients (young patients and females).

## Future perspectives

- ▶ There is a need to assess if bone–patellar tendon–bone is superior to hamstring in other postoperative areas (return to sport, pain, functional outcomes, laxity, long-term osteoarthritis).
- ▶ New techniques (multistrand hamstrings, addition of an anterolateral procedure) or other autografts (quadriceps tendon, peroneal tendon) need to be assessed in a large scale to properly compare their results with the patellar tendon or hamstrings.

Zealand (NZ), as shown in the 2018 registry, and Europe.<sup>1</sup>

Data from registries, meta-analysis and randomised controlled trials (RCTs) have provided a comprehensive overview of graft results; HT graft is linked with greater residual laxity than other autografts<sup>2</sup> and BPTB graft results in increased postoperative anterior knee pain or kneeling discomfort. Nevertheless, there are very few differences that have been clearly demonstrated between these two reconstruction techniques and the graft choice depends on surgeons' experience. Historically, studies have suggested no difference between **HT and BPTB outcomes**.

We can argue that the majority of studies:

1. Were published before 2010<sup>3–5</sup> when older techniques were used.
2. Consisted of small control group (underpowered).<sup>6–8</sup>
3. Showed some methodological limits with no robust RCTs.<sup>9 10</sup>
4. Included results from all ACLR patients, with no specification of the risk profile.<sup>2</sup>

Not surprisingly, **meta-analysis** failed to reveal differences between the two grafts.<sup>11 12</sup> There is a need for a greater magnitude of data and assessment of specific population to properly compare these grafts.

While large patient cohorts extracted from registry data are assumed to be powerful and



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reliable, these are often unqualified sample groups, without age, sex or sport level activity. Their interpretation therefore should be questioned. ACLRs tend to be a very successful procedure, thus it is hard to find differences and draw any solid or compelling conclusions.<sup>13</sup> Yet, surgeons tend to use BPTB graft specifically for **high-risk patients**, this is proven by the fact that the contralateral ACL rupture rate is higher when a BPTB autograft is used<sup>14</sup> than an HT. Such high-risk groups include patients under 20 years old who play high level cutting and pivoting sport, have hyperlaxity and/or a concomitant medial collateral ligament or a meniscal root injury. Of course, this predisposed graft choice is the main bias of all of these studies. Despite the increased use of BPTB in high-risk groups, lower graft rupture rates have been reported compared with HT graft when larger number studies are considered. Recent data confirm this trend.

## RESIDUAL LAXITY

There is scientific evidence that the **residual laxity** after an ACLR is higher with HT autografts than BPTB autografts.<sup>15 16</sup> Cristini *et al* demonstrated this over a large sample group (5462 primary ACLRs at 1-year follow-up), including 692 BPTB and 4770 HT, with a significant increase in postoperative knee laxity for HT versus BPTB ( $2.7 \pm 2.2$  mm vs  $1.7 \pm 2.6$  mm,  $p < 0.001$ ). A significantly higher rate of postoperative side-to-side difference  $> 5$  mm was found in the HT group compared with BPTB group at 1-year follow-up (4.3% vs 2.4%,  $p < 0.001$ ). Kim *et al*<sup>15</sup> showed that in a high-risk population (hyper laxity), the postoperative laxity at 2 and 5 years was significantly greater when HT was used in comparison to BPTB ( $3.5 \pm 1.4$  vs  $2.7 \pm 1.4$  at 2 years,  $p < 0.001$ ;  $4.4 \pm 1.8$  vs  $3.2 \pm 1.8$  at 5 years,  $p < 0.001$ ). These data were confirmed by subsequent large sample studies by Li *et al*<sup>17</sup> and Golblatt *et al*.<sup>18</sup>

## GRAFT FAILURE

A large registry-based study in Scandinavia<sup>19</sup> that included all ACLR in over 45 000 patients found the revision rate to be significantly lower in BPTB graft group at 5-year follow-up compared with the HT graft group (**2.8% vs 4.2%**, respectively,  $p < 0.001$ ). The lower risk of revision in the BPTB group was consistently observed across all subgroups including patient sex, age and concomitant cartilage injury.

In the Norwegian registry,<sup>1</sup> with 12 643 patients included, higher revision rates were recorded in HT graft versus BPTB graft at all follow-up times (2.8 vs 0.7 at 2 years and 5.1% vs 2.1% at 5 years). When adjusted for sex, age and type of graft, the HR for revision was 2.3 (95% CI 1.8 to 3.0) for HT grafts compared with BPTB grafts. In response to these 2014 findings, the Norwegian ACL surgeons have increased the number of BPTB ACLRs they perform. In 2010, 78% of ACLRs were hamstring and 18% were BPTB. In 2017, 33% were hamstring while 56% were BPTB, over a threefold increase in 7 years.

In 2014, Rahr-Wagner *et al*<sup>20</sup> reported a 5-year risk of graft failure of 4.45% for HT autografts versus 3.03% for BPTB autografts in 13 647 Danish patients, reflecting a 1.9% increase relative risk of graft failure with HT autografts.

Rousseau *et al*<sup>14</sup> assessed 958 patients and showed that the percentage of patients with graft rerupture was significantly lower in the BPTB group than that seen in the HT group (3.1% vs 7%,  $p = 0.023$ ) at 2-year follow-up.

Maletis *et al*,<sup>21</sup> based on the Kaiser Permanente Registry, published a higher failure rate with HT than BPTB (2.37 vs 1.94) over 17 436 procedures at 2.4-year mean follow-up. The HR was 1.53 (95% CI 1.16 to 2.02,  $p = 0.002$ ).

## HIGH-RISK PATIENTS

If we consider high-risk graft rupture patients, several studies show that the BPTB graft has a lower failure rate than HT graft. Laboute *et al*<sup>22</sup> followed 955 athletes who underwent ACLR with HT or BPTB grafts. The results demonstrated a significant difference in the rate of graft failure (6.5% for HT graft vs 2.1% for BPTB grafts) with an adjusted OR of 3.64, 95% CI (1.55 to 10.67);  $p = 0.007$ .

Ekeland *et al*<sup>23</sup> recently assessed 14 201 patients who regularly partook in high-risk sporting activities (skiing, soccer, handball) and underwent ACLR. The results demonstrated that the corresponding HR for graft type was 1.8 times higher for HT grafts than for BPTB grafts ( $p < 0.001$ ), but 2.8 times higher for individuals aged  $\leq 18$  years ( $p < 0.001$ ). **The 12-year survival of BPTB grafts was 96% compared with 93% for HT grafts** ( $p < 0.001$ ).

This trend has also been confirmed more recently when narrowing the sample group to consist only of young females. This population is known to be at a higher risk of ACL rupture than men and rupture their ACL more frequently in relation to an increasing participation in sports activities.<sup>24</sup> Therefore, if graft type can reduce failure rates, graft choice would be of paramount importance. **There is increasing evidence to suggest that the use of BPTB instead of HT graft for this patient group**<sup>25</sup> is recommended. A recent study published by Salem *et al*<sup>26</sup> showed a significant difference between these two reconstructions in young female athletes aged 15–20 years. Indeed, the failure rate accounted for 6.4% in the BPTB group, while it reached 17.5% in the HT group at a mean follow-up of 3.7 years ( $p = 0.02$ ). Interestingly, this difference was not observed in females aged 21–25 years. Shakked *et al*<sup>27</sup> assessed young women (15–25) and showed that failures of the graft occurred in 2.7% patients of the BPTB group compared with 21.4% patients of the HT group ( $p < 0.02$ ) at final follow-up. **It has been demonstrated that both female and younger patient groups have a higher risk of ACL graft rupture**, thus taking into account these two patient profiles is critical when considering graft selection. In a study presented at the 2019 ISAKOS meeting,<sup>28</sup> based on the NZ registry data, the rupture rate was significantly lower in this population when BPTB was used in comparison to HT at 2-year minimum follow-up (0% vs 5.1%;  $p = 0.023$ ).

## CONTRALATERAL ACL RUPTURE

As mentioned previously, BPTB grafts are linked with more contralateral ACL ruptures than other grafts.<sup>14 29</sup> Thompson *et al* found a 2.2 times higher failure rate for BPTB grafts in comparison to HT. This difference was statistically significant. Likewise, Rousseau *et al* observed the same trend. Webster *et al*,<sup>7</sup> over a 15-year follow-up study, found more contralateral rupture rate in the BPTB group than in the HT one but this difference was not statistically significant. However, Andernord *et al*<sup>30</sup> studied 9061 ACLRs at 5-year follow-up and did not find any significant difference between these two groups. This was confirmed recently by Pierce *et al*<sup>31</sup> who did not find any difference in the contralateral ACL rupture rate between the two grafts. Thus, the statement that BPTB leads to more contralateral failure rate is quite controversial. There are multiple reasons to explain the trend towards more contralateral ACL tears in the BPTB group, but the main one is certainly that patients from this group do not have the same risk profile as patient from the HT group. Indeed, in most places, graft choice depends on patients' profile and the tendency is to use a BPTB for patient with a high risk of rerupture. Thus, the likelihood of having a contralateral ACL tear is increased in this group of patients who already sustained an ACL

injury. On the contrary, low profile athletes or patients over 30 years old generally have an HT graft.

Of course, graft rupture rate is not the only criteria to take into consideration when it comes to graft selection in ACLR. Most studies do not assess causes of failure, and we know that **more than two-thirds are related to technical errors**.<sup>32</sup> However, other critical criteria like return to sport, laxity, return to the same level of sport do not show significant differences when large sample groups are assessed. “In addition to graft choice, the surgeon must also decide which surgical technique to use. Anteromedial and transtibial techniques are the most commonly used, with most orthopaedic surgeons using the anteromedial technique, as it allows for unconstrained anatomic placement of both the tibial and femoral tunnels”.<sup>33</sup>

### DONOR SITE MORBIDITY

Anterior pain remains a controversial issue and is **a common reason for not choosing the BPTB graft**. Rousseau *et al*<sup>14</sup> reported no difference at 2-year follow-up between HT and BPTB while there were more patients complaining of anterior knee pain in the BPTB group at 1 year. Minimal invasive harvesting techniques could assist in pain reduction.<sup>34 35</sup> Moreover, to avoid patellar fracture or PT rupture, smaller bone block harvests can be performed. Anterior knee pain or kneeling pain are higher with BPTB than other grafts,<sup>36</sup> and functional scores are variably in favour of HT<sup>16 37</sup> or similar between these two grafts.<sup>38 39</sup> The knee flexion strength is reduced with HT grafts and it is not clear if return to sport is better with one or the other graft.

In order to avoid BPTB complications, there is a growing interest in use of the **quadriceps tendon**<sup>40</sup> (QT) as a primary graft. Cavaignac *et al*<sup>41</sup> showed the use of the QT graft leads to an equal or better patient-reported outcomes and less residual laxity in comparison to an HT graft over a mean follow-up of 3.6 years. Additionally, it was not associated with an increased morbidity in comparison to the HT tendon, yet clearly avoids the previously discussed complications associated with the BPTB graft.

Mouarbes *et al*<sup>42</sup> recently published a meta-analysis, concluding that “QT autograft had comparable clinical and functional outcomes and graft survival rate compared with BPTB and HT autografts. **However, QT autograft showed significantly less harvest site pain compared with BPTB autograft and better functional outcome scores compared with HT autograft**”. Notwithstanding, the failure rate in high-risk patients is still to be assessed through registry data and or RCTs to state the superiority of the QT graft. The Danish Registry<sup>43</sup> reported a greater failure rate with QT grafts. They showed a 4.9% failure rate for QT, a 2.7% failure rate for HT and a 1.6% failure rate for BPTB. Both all soft-tissue QT grafts and QT grafts with a bone block had a similar failure rate.

### CONCLUSION

Despite an abundance of new technologies and advances in this surgical field, BPTB still has the lowest failure rate and is more commonly performed in patients who are considered high risk. Complications after BPTB harvest can be debilitating and can have serious long-term consequences. Consequently, the decision to use this graft instead of lower morbidity grafts like HT, quadriceps tendon or allograft has to be justified by significantly better results. In the case of high-risk patients, specifically young female patients, this certainly appears to be the case. Thus, BPTB is becoming more popular among surgeons, particularly

in NZ where 90% of sports knee surgeons use BPTB in high-risk patient. Similar trends have also been noted in Scandinavia.

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### REFERENCES

- Persson A, Fjeldsgaard K, Gjertsen J-E, *et al*. Increased risk of revision with hamstring tendon grafts compared with Patellar tendon grafts after anterior cruciate ligament reconstruction: a study of 12,643 patients from the Norwegian cruciate ligament registry, 2004-2012. *Am J Sports Med* 2014;42:285-91.
- Chee MYK, Chen Y, Pearce CJ, *et al*. Outcome of Patellar tendon versus 4-Strand hamstring tendon autografts for anterior cruciate ligament reconstruction: a systematic review and meta-analysis of prospective randomized trials. *Arthroscopy* 2017;33:450-63.
- Aglietti P, Giron F, Buzzi R, *et al*. Anterior cruciate ligament reconstruction: bone-patellar tendon-bone compared with double semitendinosus and gracilis tendon grafts. A prospective, randomized clinical trial. *J Bone Joint Surg Am* 2004;86:2143-55.
- Pinczewski LA, Lyman J, Salmon LJ, *et al*. A 10-year comparison of anterior cruciate ligament reconstructions with hamstring tendon and Patellar tendon autograft. *Am J Sports Med* 2007;35:564-74.
- Wagner M, Kääh MJ, Schallock J, *et al*. Hamstring tendon versus Patellar tendon anterior cruciate ligament reconstruction using biodegradable interference fit fixation. *Am J Sports Med* 2005;33:1327-36.
- Jansson KA, Linko E, Sandelin J, *et al*. A prospective randomized study of Patellar versus hamstring tendon autografts for anterior cruciate ligament reconstruction. *Am J Sports Med* 2003;31:12-18.
- Webster KE, Feller JA, Hartnett N, *et al*. Comparison of Patellar tendon and hamstring tendon anterior cruciate ligament reconstruction: a 15-year follow-up of a randomized controlled trial. *Am J Sports Med* 2016;44:83-90.
- Leyts T, Salmon L, Waller A, *et al*. Clinical results and risk factors for reinjury 15 years after anterior cruciate ligament reconstruction: a prospective study of hamstring and Patellar tendon grafts. *Am J Sports Med* 2012;40:595-605.
- Biau DJ, Tournoux C, Katsahian S, *et al*. Bone-patellar tendon-bone autografts versus hamstring autografts for reconstruction of anterior cruciate ligament: meta-analysis. *BMJ* 2006;332:995-1001.
- Xie X, Liu X, Chen Z, *et al*. A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. *Knee* 2015;22:100-10.
- Gabler CM, Jacobs CA, Howard JS, *et al*. Comparison of graft failure rate between autografts placed via an anatomic anterior cruciate ligament reconstruction technique: a systematic review, meta-analysis, and meta-regression. *Am J Sports Med* 2016;44:1069-79.
- Mohtadi NGH, Chan DS, Dainty KN, *et al*. Patellar tendon versus hamstring tendon autograft for anterior cruciate ligament rupture in adults. *Cochrane Database Syst Rev* 2011;22.
- Samuelsen BT, Webster KE, Johnson NR, *et al*. Hamstring autograft versus Patellar tendon autograft for ACL reconstruction: is there a difference in graft failure rate? A meta-analysis of 47,613 patients. *Clin Orthop Relat Res* 2017;475:2459-68.
- Rousseau R, Labruyere C, Kajetanek C, *et al*. Complications after anterior cruciate ligament reconstruction and their relation to the type of graft: a prospective study of 958 cases. *Am J Sports Med* 2019;47:2543-9.
- Kim S-J, Choi CH, Kim S-H, *et al*. Bone-patellar tendon-bone autograft could be recommended as a superior graft to hamstring autograft for ACL reconstruction in patients with generalized joint laxity: 2- and 5-year follow-up study. *Knee Surg Sports Traumatol Arthrosc* 2018;26:2568-79.
- Cristiani R, Sarakatsianos V, Engström B, *et al*. Increased knee laxity with hamstring tendon autograft compared to Patellar tendon autograft: a cohort study of 5462 patients with primary anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2019;27:381-8.

- 17 Li S, Su W, Zhao J, *et al.* A meta-analysis of hamstring autografts versus bone–patellar tendon–bone autografts for reconstruction of the anterior cruciate ligament. *Knee* 2011;18:287–93.
- 18 Goldblatt JP, Fitzsimmons SE, Balk E, *et al.* Reconstruction of the anterior cruciate ligament: meta-analysis of Patellar tendon versus hamstring tendon autograft. *Arthroscopy* 2005;21:791–803.
- 19 Gifstad T, Foss OA, Engebretsen L, *et al.* Lower risk of revision with Patellar tendon autografts compared with hamstring autografts: a registry study based on 45,998 primary ACL reconstructions in Scandinavia. *Am J Sports Med* 2014;42:2319–28.
- 20 Rahr-Wagner L, Thillemann TM, Pedersen AB, *et al.* Comparison of hamstring tendon and Patellar tendon grafts in anterior cruciate ligament reconstruction in a nationwide population-based cohort study: results from the Danish registry of knee ligament reconstruction. *Am J Sports Med* 2014;42:278–84.
- 21 Maletis GB, Inacio MCS, Funahashi TT. Risk factors associated with revision and contralateral anterior cruciate ligament reconstructions in the Kaiser Permanente ACLR registry. *Am J Sports Med* 2015;43:641–7.
- 22 Laboute E, James-Belin E, Puig PL, *et al.* Graft failure is more frequent after hamstring than Patellar tendon autograft. *Knee Surg Sports Traumatol Arthrosc* 2018;26:3537–46.
- 23 Ekland A, Engebretsen L, Fenstad AM, *et al.* Similar risk of ACL graft revision for alpine skiers, football and handball players: the graft revision rate is influenced by age and graft choice. *Br J Sports Med* 2019;bjsports-2018-100020.
- 24 Zbrojkiewicz D, Vertullo C, Grayson JE. Increasing rates of anterior cruciate ligament reconstruction in young Australians, 2000–2015. *Med J Aust* 2018;208:354–8.
- 25 Kamien PM, Hydrick JM, Replogle WH, *et al.* Age, graft size, and Tegner activity level as predictors of failure in anterior cruciate ligament reconstruction with hamstring autograft. *Am J Sports Med* 2013;41:1808–12.
- 26 Salem HS, Varzhapetyan V, Patel N, *et al.* Anterior cruciate ligament reconstruction in young female athletes: Patellar versus hamstring tendon autografts. *Am J Sports Med* 2019;47:2086–92.
- 27 Shakked R, Weinberg M, Capo J, *et al.* Autograft choice in young female patients: patella tendon versus hamstring. *J Knee Surg* 2017;30:258–63.
- 28 Clatworthy M, Powell A. Does a thicker hamstring or patella tendon graft reduce the failure rate in anterior cruciate ligament reconstruction in young patients? 12th Biennial ISAKOS Congress, Cancun, Mexico, 2019:86.
- 29 Thompson SM, Salmon LJ, Waller A, *et al.* Twenty-Year outcome of a longitudinal prospective evaluation of isolated endoscopic anterior cruciate ligament reconstruction with Patellar tendon or hamstring autograft. *Am J Sports Med* 2016;44:3083–94.
- 30 Andernord D, Desai N, Björnsson H, *et al.* Predictors of contralateral anterior cruciate ligament reconstruction: a cohort study of 9061 patients with 5-year follow-up. *Am J Sports Med* 2015;43:295–302.
- 31 Pierce T, Issa K, Cassidy K, *et al.* Risk factors for contralateral ACL injury: a single institution Case–Control study. *J Knee Surg* 2018;31:846–50.
- 32 Diamantopoulos AP, Lorbach O, Paessler HH. Anterior cruciate ligament revision reconstruction: results in 107 patients. *Am J Sports Med* 2008;36:851–60.
- 33 Clatworthy M, Sauer S, Roberts T. Transportal central femoral tunnel placement has a significantly higher revision rate than transtibial am femoral tunnel placement in hamstring ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2019;27:124–9.
- 34 Beaufils P, Gaudot F, Drain O, *et al.* Mini-invasive technique for bone Patellar tendon bone harvesting: its superiority in reducing anterior knee pain following ACL reconstruction. *Curr Rev Musculoskelet Med* 2011;4:45–51.
- 35 Koh E, Oe K, Takemura S, *et al.* Anterior cruciate ligament reconstruction using a Bone–Patellar Tendon–Bone autograft to avoid Harvest-Site morbidity in knee arthroscopy. *Arthrosc Tech* 2015;4:e179–84.
- 36 Poehling-Monaghan KL, Salem H, Ross KE, *et al.* Long-Term outcomes in anterior cruciate ligament reconstruction: a systematic review of Patellar tendon versus hamstring autografts. *Orthop J Sports Med* 2017;5.
- 37 Hamrin Senorski E, Svantesson E, Baldari A, *et al.* Factors that affect patient reported outcome after anterior cruciate ligament reconstruction—a systematic review of the Scandinavian knee ligament registers. *Br J Sports Med* 2019;53:410–7.
- 38 Mohtadi NG, Chan DS. A randomized clinical trial comparing Patellar tendon, hamstring tendon, and Double-Bundle ACL reconstructions: patient-reported and clinical outcomes at 5-year follow-up. *J Bone Joint Surg Am* 2019;101:949–60.
- 39 Sajovic M, Strahovnik A, Dernovsek MZ, *et al.* Quality of life and clinical outcome comparison of semitendinosus and gracilis tendon versus Patellar tendon autografts for anterior cruciate ligament reconstruction. *Am J Sports Med* 2011;39:2161–9.
- 40 Xerogeanes JW. Quadriceps tendon graft for anterior cruciate ligament reconstruction: the graft of the future! *Arthroscopy* 2019;35:696–7.
- 41 Cavaignac E, Coulin B, Tscholl P, *et al.* Is quadriceps tendon autograft a better choice than hamstring autograft for anterior cruciate ligament reconstruction? A comparative study with a mean follow-up of 3.6 years. *Am J Sports Med* 2017;45:1326–32.
- 42 Mouarbes D, Menetrey J, Marot V, *et al.* Anterior cruciate ligament reconstruction: a systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus Bone–Patellar Tendon–Bone and Hamstring–Tendon autografts. *Am J Sports Med* 2019;47:3531–40.
- 43 Lind M, Strauss MJ, Nielsen T, *et al.* Quadriceps tendon autograft for anterior cruciate ligament reconstruction is associated with high revision rates: results from the Danish knee ligament registry. *Knee Surg Sports Traumatol Arthrosc* 2019;14.

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