

# Surgical Repair of Distal Biceps Femoris Avulsion Injuries in Professional Athletes

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**Background:** Understanding the optimal management of distal biceps femoris avulsion injuries is critical for restoring preinjury function, restoring hamstring muscle strength, increasing range of motion, and minimizing risk of complications and recurrence. Due to the rarity of these injuries, prognosis and outcomes within the literature are limited to case reports and small case series.

**Purpose:** To assess the effect of surgical repair for acute distal avulsion injuries of the biceps femoris tendon on (1) return to preinjury level of sporting function and (2) time to return to preinjury level of sporting function, patient satisfaction, and complications.

**Study Design:** Case series; Level of evidence, 4.

**Methods:** This prospective single-surgeon study included 22 elite athletes (18 men [82%], 4 women [18%]; mean age, 26 years; age range, 17-35 years; mean body mass index,  $25.3 \pm 4.1$  kg/m<sup>2</sup>) undergoing primary suture anchor repair of avulsion injuries of the distal biceps femoris confirmed on preoperative magnetic resonance imaging. Predefined outcomes relating to time for return to sporting activity, patient satisfaction, complications, and injury recurrence were recorded at regular intervals after surgery. Minimum follow-up time was 12 months (range, 12.0-26.0 months) from the date of surgery.

**Results:** The mean time from injury to surgical intervention was 12 days (range, 2-28 days). All study patients returned to their preinjury level of sporting activity, predominately professional soccer or rugby. Mean time from surgical intervention to return to full sporting activity was  $16.7 \pm 8.7$  weeks. At 1- and 2-year follow-up, all study patients were still participating at their preinjury level of sporting activity. There was no incidence of primary injury recurrence, and no patients required further operation to the biceps origin.

**Conclusion:** Surgical repair of acute avulsion injuries of the distal biceps femoris facilitated early return to preinjury level of function with low risk of recurrence, low complication rate, and high patient satisfaction in elite athletes. Suture anchor repair of these injuries should be considered a reliable treatment option in athletes with high functional demands to permit an early return to sport with restoration of hamstring strength.

**Keywords:** biceps femoris; hamstrings; avulsion; return to sport; recurrence; surgical treatment

Hamstring injuries are among the most frequently injured muscle group in high-level sports, leading to long periods of recovery and a high risk of recurrence.<sup>2,10,12</sup> The biceps femoris is most frequently injured and accounts for 57% to 87% of all hamstring strains, most commonly affecting the proximal or distal musculotendinous junction.<sup>15,17,31,34,44</sup> The management of proximal hamstring avulsion has been well-documented in the literature, with a number of

studies advocating for surgical reattachment.<sup>§</sup> Avulsion injuries of the hamstring tendinous complex are rare; in particular, distal avulsion insertional injuries are extremely rare and account for only 2% of all hamstring injuries.<sup>29</sup>

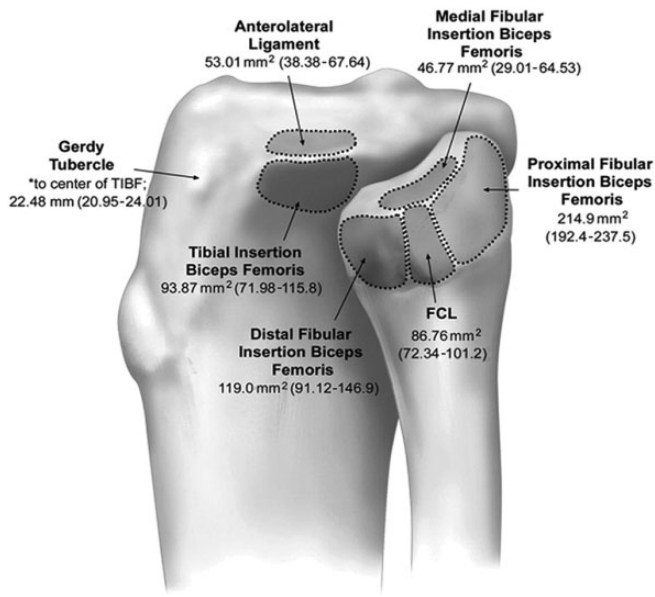
The biceps femoris is the major flexor of the lower limb and functions as a dynamic and static stabilizer of the knee joint.<sup>10,28</sup> Muscular concentric contraction accounts for 30% to 85% of strength during knee flexion and also functions in hip extension and external rotation.<sup>8,13,30,33,46</sup>

The biceps femoris functions as part of the posterolateral corner (PLC) capsular-ligamentous complex in combination with the popliteal muscle, popliteofibular ligament, fibular collateral ligament (FCL), and posterolateral articular capsule. It not only acts as a dynamic and static

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<sup>§</sup>References 2, 4, 5, 10, 19, 22, 26, 41, 51, 52.

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**Figure 1.** The insertional locations and footprint area of the biceps femoris, fibular collateral ligament (FCL), and anterolateral ligament, with footprint surface area presented as the mean (range) in mm<sup>2</sup>. Image from Branch and Anz,<sup>6</sup> used under <https://creativecommons.org/licenses/by-nc-nd/4.0>. TIBF, tibial insertion biceps femoris.

stabilizer but also resists external rotation of the tibia on the femur.<sup>30,33,46</sup> Biarticular motion, dual antagonistic innervation, and potential quadriceps femoris contraction all predispose the biceps femoris to musculotendinous injury.<sup>31,44,47</sup>

The biceps femoris is the most lateral hamstring muscle and has 2 heads of origin. The long head of the biceps femoris originates from the posteroinferior ischial tuberosity as part of the conjoint tendon and is a biarticular muscle innervated by the tibial nerve. The short head, however, originates from just medial to the linea aspera of the diaphyseal distal femur, the lateral supracondylar ridge, and the lateral intramuscular septum and is uniaxial and innervated by the common peroneal nerve.<sup>16,44</sup> The distal biceps femoris is also a complex structure anatomically. Qualitative and quantitative anatomic studies have described consistent insertional footprints but with varying terminology.<sup>7,32,44,45</sup> The cadaveric anatomic study by Branch and Anz<sup>6</sup> provided pertinent osseous landmarks of the distal biceps femoris 4 insertional footprints: a tibial footprint, proximal fibular footprint, distal fibular

footprint, and medial fibular footprint (Figure 1). The proximal and distal fibular footprints are predominately supplied by fibers from the long head, the medial fibular footprint by fibers of the short head, and the tibial footprint equivocally supplied by both heads.<sup>6</sup> With this anatomic understanding, Branch et al<sup>7</sup> performed a further biomechanical study on tensile performance of alternate distal biceps femoris repair constructs and associated failure loads. However, to date, these studies have not yet been correlated with clinical studies.

Avulsion injuries of the biceps femoris are seen within multiligamentous injuries of the knee, more specifically those involving the PLC. Isolated tendon injuries involving the distal biceps femoris are rare and more commonly involve the musculotendinous junction rather than to distal insertional avulsion.<sup>27,28,33</sup> Studies reporting the outcomes of biceps femoris avulsion injuries are limited to case reports and small case series.<sup>1,28</sup> The optimal management of proximal hamstring avulsion injuries is almost uniformly recognized as surgical.<sup>22,28</sup>

Understanding the optimal management of distal biceps femoris avulsion injuries is critical for restoring preinjury function, restoring hamstring muscle strength, increasing range of motion (ROM), and minimizing risk of complication and recurrence. The primary aim of the current study was to assess the effect of surgical repair for acute distal avulsion injuries of the biceps femoris tendon on return to preinjury level of sporting function. The secondary aims were to assess the effect of surgical repair on time to return to preinjury level of sporting function, patient satisfaction, and complications. The study hypothesis was that surgical repair of these acute injuries would enable return to preinjury level of sporting function with a low risk of recurrence.

## METHODS

The study was prospectively reviewed by the hospital review board, which advised that further research ethics committee approval was not required. Written informed consent for participation was obtained from all study patients.

### Patient Selection

This prospective study included 22 professional athletes undergoing surgical intervention for acute distal avulsion injuries of the biceps femoris tendon using a suture anchor repair technique. All operative procedures were performed

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Ethical approval for this study was obtained from The Princess Grace Hospital.

TABLE 1  
Demographics and Baseline Data for Study Patients  
Undergoing Surgical Repair for Acute Distal Avulsion  
Injuries of the Biceps Femoris (N = 22)<sup>a</sup>

Category	Value
Age, y <sup>b</sup>	26 (17-35)
Sex	
Female	4 (18)
Male	18 (82)
BMI (kg/m <sup>2</sup> ) <sup>c</sup>	25.3 ± 4.1
ASA score (I-IV)	
I	22 (100)
II-IV	0
Laterality	
Right	14 (64)
Left	8 (36)
Sporting activity	
Rugby	10 (45)
Soccer	9 (41)
Athletics	2 (9)
Gymnastics	1 (5)
Time from injury to surgery, days <sup>b</sup>	12 (2-28)

<sup>a</sup>Data are presented as No. (%) unless otherwise indicated. ASA, American Society of Anesthesiologists; BMI, body mass index.

<sup>b</sup>Data are presented as mean (range).

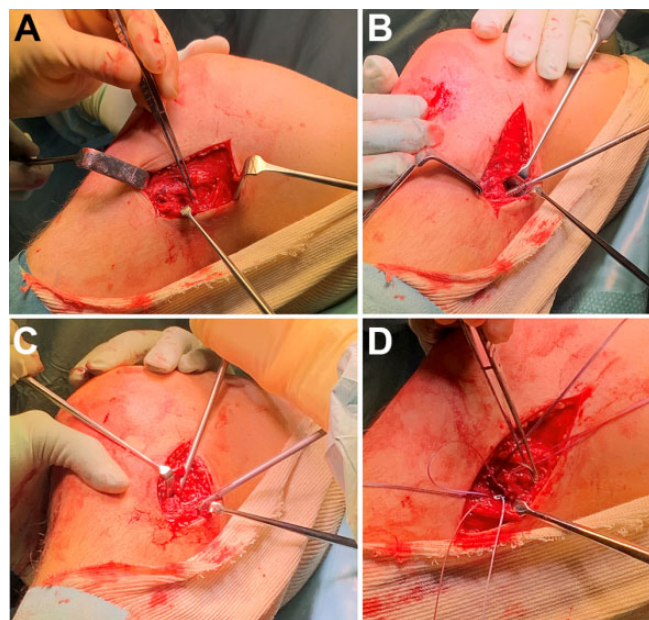
<sup>c</sup>Data are presented as mean ± SD.

by the senior author (F.S.H.) between 2005 and 2018. Baseline and demographic data for all study patients are shown in Table 1.

Preoperative magnetic resonance imaging (MRI) was undertaken in all study patients to confirm diagnosis and identify any concurrent injuries. All operative procedures were performed by the senior author. Inclusion criteria for study participation included the following: injury sustained within 4 weeks of operative intervention; MRI to confirm avulsion injuries of biceps femoris ± FCL or capsule injury; and clinical loss of strength and/or flexibility of the hamstring muscle group. Exclusion criteria included recurrent biceps femoris avulsion injury after nonoperative treatment (n = 9); injury sustained greater than 4 weeks before operative intervention (n = 8); and multiligamentous injury involving the PLC or cruciate ligaments (n = 21).

### Surgical Technique

All operations were performed under general anesthesia with the patient in the supine position (Figure 2). A posterolateral curvilinear longitudinal incision centered at the level of the fibular head, approximately 8 to 12 cm over the lateral aspect of the popliteal fossa, was made. Unipolar diathermy was used to incise the underlying subcutaneous tissue in line with the skin incision. The overlying fascia of the biceps femoris was identified and incised longitudinally. The peroneal nerve was identified and protected. The retracted and defunct biceps femoris tendon was traced to its site of injury, and with care, adhesive scar tissue was



**Figure 2.** Intraoperative photograph showing (A) a remnant stump of the biceps femoris tendinous insertion after distal avulsion injury, (B) insertion of the first suture anchor into the posterolateral aspect of the fibular head, (C) insertion of the second anchor into the superomedial aspect fibular head, and (D) suturing of the anchor sutures into the free end of the avulsed tendon with a modified Kessler technique.

excised using diathermy along the tendon length. Any underlying hematoma or seroma was evacuated. The FCL was identified and assessed to ensure its integrity. The proximal end of the avulsed or torn biceps femoris tendon was refashioned, excising any friable scar tissue and tensioned using a stay suture to mobilize the muscle to its preinjury length. Tendon quality was reassessed to ensure it was not under any undue tension when reapproximated to its distal insertion site at the fibular head.

For avulsion type injuries, the fibular head insertional footprint was prepared and 2 or 3 Healix 5.5-mm suture anchors (DePuy Synthes) were inserted into the fibular head posterior/adjacent to the FCL insertion under direct vision. Each anchor had 2 nonabsorbable ultrahigh molecular weight polyethylene fiber sutures, which were stitched into the free end of the avulsed tendon with a modified Kessler technique.

The knee was manipulated through a full ROM to ensure appropriate tension on the biceps femoris repair and confirm that the peroneal nerve was not tethered throughout the arc of motion. The overlying hamstring fascia was closed with absorbable sutures. The wound was copiously irrigated with normal saline, and absorbable sutures were used to perform a layered closure of the overlying fascia, subcutaneous fat, and skin. All patients were placed in a hinged knee brace for 4 weeks.



## Postoperative Rehabilitation

All patients underwent a standardized milestone-based rehabilitation program supervised by an experienced sports physiotherapist. The rehabilitation program was divided into 4 distinct phases.

**Phase 1:** Rest, ice, compression, and elevation; partial weightbearing with crutches; aspirin 75 mg once daily; nonsteroidal anti-inflammatory drugs; limited excessive combined hip flexion and knee extension; normalization of gait.

**Phase 2:** Regaining of pain-free ROM, full weightbearing, concentric and eccentric training, core strengthening.

**Phase 3:** Aerobic conditioning with light jogging, cycling, and swimming; muscle strengthening with resistance exercises; double- and single-leg squats; quadriceps extension; hamstring curls; sport-specific training.

**Phase 4:** Return to full sporting activity when fully pain-free ROM, muscle strength 90% of uninjured limb, and no concerns with sport-specific training.

## Outcome Measures

All study patients were reviewed by the operating surgeon in the outpatient clinic at regular intervals until return to play. Study outcomes were recorded by a specialist nurse practitioner preoperatively and at predefined intervals postsurgically. All outcomes at 3 months, 1 year, and 2 years after surgery were collected during clinical consultation or collated by telephone conversation or email (due to the wide geographical location of study patients). Outcome measures collected included return to sporting activity, patient satisfaction, postoperative complications, and injury recurrence.

Time from surgical intervention to full return to sporting activity was collected in all study patients. All complications with their respective treatments and outcomes within 2 years of the primary surgery were recorded. Recurrence of injury or reoperation was duly recorded. Patient satisfaction was recorded after surgery using the Musculoskeletal Outcomes Data Evaluation and Management System that scores patient satisfaction on a scale of 1-5 (1, very unsatisfied; 2, unsatisfied; 3, neutral; 4, satisfied; and 5, very satisfied).<sup>21</sup>

## RESULTS

All 22 patients recruited into this study completed follow-up to a minimum of 12 months. The mean follow-up time was 16 months (range, 12-26 months) from the date of surgery.

The mean time from injury to surgical intervention was 12 days (range, 2-28 days).

### Return to Function and Recurrence

All study patients returned to their preinjury level of sporting activity. The mean time from surgical intervention to return to full sporting activity was  $16.7 \pm 8.7$  weeks. At the

1- and 2-year follow-up, all study patients were still participating at their preinjury level of sporting activity. No study patients had a recurrence of the primary injury.

### Patient Satisfaction

Surgical repair of acute distal hamstring injuries was associated with high levels of patient satisfaction at 1 and 2 years after surgery. At a minimum of 1-year follow-up, 20 patients (91%) were very satisfied and 2 patients (9%) were satisfied about the outcomes of their surgery.

### Complications

Two patients had minor postoperative complications during the follow-up period. One patient developed an acute suture abscess, which resolved after oral antibiotics, and the patient had no delay with regard to return to sport (15 weeks). Another patient developed a hypertrophic scar. This was not associated with any functional deficit, and the patient returned to sport by 16 weeks. No other complications were observed within the 26-month follow-up period. Specifically, there were no episodes of venous thromboembolism or neurological complications. There was no incidence of injury recurrence and no patients required further operation.

## DISCUSSION

This study demonstrates that surgical repair of acute distal biceps femoris avulsion injuries is successful in facilitating accelerated rehabilitation and early return to preinjury sporting activity. We report an early return to sport and low incidence of complication or recurrence at a short-term follow-up. To our knowledge, this is the first prospective, as well as the largest, study to report on the efficacy of surgical repair for acute distal biceps femoris avulsion ruptures, and it provides valuable prognostic information on functional outcomes and return to preinjury sporting activity after repair.

Inferior outcomes of nonoperatively managed athletes with high-grade hamstring injuries have been accredited to the inferior biomechanical strength of immature scar tissue within the muscle complex; decreased tensile strength; and reduced compliance during eccentric and concentric contraction leading to reinjury.<sup>23,25</sup> Suture anchor repair of distal biceps femoris avulsions reduces formation of scar tissue, maintains the vector of contraction, and restores muscle tension allowing biceps femoris strength and compliance to be restored.

The current literature highlights the lack of knowledge in this area of hamstring surgery with only 17 cases of distal biceps femoris avulsion injuries being reported; see Appendix Table A1 for a summary of available studies.<sup>11</sup> The mean age was 34.8 years (range, 18-55 years). Injuries were most common in elite athletes (47%), and all cases sustained injuries during sporting activities. Of the patients, 87% sustained injuries through a noncontact mechanism, with knee hyperextension and soccer being the

<sup>11</sup>References 1, 3, 9, 20, 30, 33, 36, 37, 39, 40, 42, 49.

most common mechanism of injury and sporting activity, respectively. Of the injuries, 87% were isolated. The mean time to surgery was 21.7 days (range, 2-120 days). Of the cases, 87% were treated with acute surgical repair after rupture (within 21 days). Two cases (12%) were surgically managed after chronic ruptures with associated significant functional impairment. Surgical repair was made using suture anchors in 12 cases and transosseous drill hole suture repair in 5 cases (see the Appendix).

## Return to Sport

Distal biceps femoris avulsion injuries are associated with a variable return-to-sport timing, which is unacceptable in the cohort of elite athletes who demand an early return to sport and low risk of recurrence. Within the literature, the mean time to return to sport for athletes is 5.3 months (range, 2-12 months) (see the Appendix). Knapik et al<sup>28</sup> reported a systematic review of 22 distal biceps femoris injuries, including avulsion and musculotendinous junction injuries. After surgical repair, the mean time to return to sport was quicker for musculotendinous junction injuries compared with avulsion injuries:  $4.2 \pm 2.6$  months versus  $6.4 \pm 3.2$  months, respectively. In the largest study to date for distal biceps femoris avulsion repairs ( $n = 4$ ), Ahearn and Wood<sup>1</sup> reported a mean return to sport of 5 months. In our study, we observed earlier return to sport in elite athletes at  $16.7 \pm 8.7$  weeks ( $3.8 \pm 2.0$  months) after surgical repair of the distal biceps femoris. This may be multifactorial. Our study population included only professional athletes; the interval from injury to surgical intervention was shorter; and other factors such as surgical technique and athlete enrollment in a postoperative milestone-based rehabilitation program may have contributed.

The prospective study by Kayani et al<sup>27</sup> of 34 professional athletes after surgical repair of acute distal musculotendinous T junction injuries of biceps femoris within our unit showed that athletes returned to their preinjury level of sporting activity with a mean time of  $11.7 \pm 3.6$  weeks. Comparing our cohort of professional athletes with the current study, this demonstrates that the mean time to return to sport was shorter for musculotendinous junction injuries compared with avulsion injuries after surgical repair ( $11.7 \pm 3.6$  vs  $16.7 \pm 8.7$  weeks, respectively). This is in conjunction with findings from the systematic review by Knapik et al<sup>28</sup> discussed above.

## Acute Versus Chronic Management and Complications

Similar to chronic proximal hamstring avulsions,<sup>10,51</sup> the outcomes of surgical repair of a chronic distal avulsion of the biceps femoris have been shown to have greater duration to return to play ( $\geq 9$  months)<sup>1,14</sup> and poorer outcomes than with acute repair.<sup>37</sup> In addition, delays in the surgical management of alternative proximal and distal complete hamstring ruptures are associated with increased scar formation and tendon hypertrophy, resulting in tethering to adjacent neurological structures and resultant paraesthesia or motor weakness.<sup>11,43,50</sup> Day et al<sup>14</sup> described

preoperative common peroneal neuritis before surgical repair and neurolysis in their delayed management of a distal rupture of the biceps femoris at 3 months after injury. In our study, early surgical intervention helped to limit the formation of scar tissue or adhesions that cause tethering to the adjacent nervous structures. None of the current study's patients required intraoperative neurolysis, and all patients made a full neurological recovery.

Within the literature, nonoperative management for distal biceps femoris rupture is limited to a single case report of a 42-year-old recreational hockey player, who 2 years prior had sustained an ipsilateral proximal biceps femoris and semitendinosus avulsion injury managed surgically.<sup>48</sup> Watura and Harries<sup>48</sup> reported outcomes after nonoperative management of the subsequent injury, and the patient returned to sport after 10 months from injury, although reported ipsilateral hamstring weakness and difficulty sprinting. Other reports of distal biceps femoris injuries managed nonoperatively all involve injuries confined to the distal musculotendinous junction with mixed outcomes.<sup>13,18,24</sup>

High-grade distal hamstring injuries managed nonoperatively are associated with enhanced scar formation, tendon hypertrophy, and soft tissue adhesions resulting in refractory pain.<sup>38</sup> This adhesive scarring process, paralleled by tendon hypertrophy, results in fascial strictures within the popliteal region and typically impairs athlete acceleration during full sprinting speed.<sup>38</sup> Surgical repair not only provides restoration of native anatomy of the biceps femoris insertion, minimizing potential hamstring weakness or knee instability, but also minimizes this hypertrophic inflammatory process and maximizes a successful return to sport. In particular, in the cohort of elite athletes, tendon restoration to original length, and therefore muscle tension, is critical for a return to pre-injury level of sporting activity. This study demonstrates excellent results after acute surgical repair with early return to sport without primary injury recurrence.

Due to the lack of published cases of nonoperatively managed injuries, combined with the lack of standardization of rehabilitation programs, inclusion and exclusion criteria, validated function, or isokinetic strength outcomes, one is unable to directly compare operative versus nonoperative management in such injuries.

In our study, we report a low complication rate with no incidence of recurrence or reoperation. Two patients developed minor complications, a suture abscess and hypertrophic scarring. Both resolved with nonoperative management and no functional impairment or delay in return to sport. Similarly, Ahearn and Wood,<sup>1</sup> in their study of 10 distal hamstring avulsion repairs, reported delayed wound healing in 1 patient. In contrast to our study where no study patients developed venous thromboembolisms, Ahearn and Wood reported a 20% rate of postoperative deep vein thromboembolism (20%;  $n = 2$ ).

## Biomechanical Studies

In contrast to biomechanical studies, we demonstrate that the suture anchor technique for distal biceps femoris avulsion injuries is a reliable surgical method with low failure rates. Branch et al<sup>7</sup> performed a cadaveric biomechanical study

quantifying distal tendinous failure loads for native biceps femoris, simple fibular repair, fibular repair with tibial suture bridge, and transosseous repair. They reported superior results in transosseous biceps femoris repair over alternative repair techniques, although all repair techniques demonstrated failure loads well below native values of the biceps femoris. However, this cadaveric study included specimens with a mean age of 59 years and testing performed time zero-day repair strength, nonequivocal to repair in vivo in the population undergoing these procedures and detailed postoperative rehabilitation program within the literature and the athletes in this study. An increased number of suture anchors or suture bridges have demonstrated superior efficacy in equivalent rotator cuff studies aiming to achieve fixation to a larger surface area of the insertional footprint.<sup>35</sup>

### Limitations

The key limitation to our study is that due to the rarity of these injuries, we report on a small number of cases. Second, due to the wide geographical spread of athletes and professional nature of these elite athletes, it was not possible to formally and objectively assess hamstring strength or functional scores prior to their return to sport. Third, there was no control group of athletes managed nonoperatively for direct comparison. All participants were professional athletes, and it would have been inappropriate to randomize them into an operative or nonoperative pathway given the risk of failure to return to their preinjury sporting level. Accordingly, the results were specific to elite athletes, all aged  $\leq 35$  years and of ASA grade I; therefore, we caution against extrapolating these findings to older patients who are not elite athletes. Finally, study outcomes were limited to a short-term follow-up at a maximum of 26 months.

### CONCLUSION

Surgical repair of acute avulsion injuries of the distal biceps femoris facilitated early return to preinjury level of function with low risk of recurrence, low complication rate, and high patient satisfaction at short-term follow-up in elite athletes. Suture anchor repair of these injuries should be considered as a reliable treatment option in athletes with high functional demands to permit an early return to sport with restoration of hamstring strength.

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APPENDIX

TABLE A1  
Literature Review of Distal Biceps Femoris Avulsion Injuries (N = 17)<sup>a</sup>

Lead Author (Year)	N	Patient Age, y	Injury Pattern	Time to Surgery	Treatment	RTS, mo	Patient Details	Mechanism	Outcome/Complications	Rehabilitation
Ahearn <sup>1</sup> (2020)	4	~ 42	Avulsion	33 d (12-89)	Suture anchor	5 (3-9)	Elite/competitive/recreational (rugby/sprinting)	NR	<ul style="list-style-type: none"> <li>4/4 excellent functional score</li> <li>Strength testing at 90° KF = 104%, at 15° KF = 107%.</li> <li>DVT + delayed healing reported*</li> </ul>	NR
Budhraj <sup>9</sup> (2020)	1	34	Avulsion	9 d	Transosseous suture button	4	Elite/competitive (soccer)	Hyperextension (reverse kick)	<ul style="list-style-type: none"> <li>No functional testing</li> <li>Painless prominent femoral head at 22 mo postop</li> </ul>	<ul style="list-style-type: none"> <li>0-1/52, immobilized at 30° KF in HKB</li> <li>1-5/52, NWB + increased progressively to FROM</li> <li>6/52, FWB + intensive rehab</li> </ul>
Aldebeyan <sup>3</sup> (2016)	1	24	Avulsion (multi-lig)	Acute	Suture anchor (FCL + SM repair)	11	Elite (NFL)	Contact injury (pure hyperextension)	<ul style="list-style-type: none"> <li>NR</li> <li>Pain-free ROM + sport-specific rehabilitation program</li> </ul>	<ul style="list-style-type: none"> <li>0-2/52, immobilized at 90° HKB</li> <li>2-4/52, HKB + passive FROM</li> <li>8/52, commenced hamstring strengthening</li> </ul>

(continued)

Table A1 (continued)

Lead Author (Year)	N	Patient Age, y	Injury Pattern	Time to Surgery	Treatment	RTS, mo	Patient Details	Mechanism	Outcome/Complications	Rehabilitation
Oshima <sup>36</sup> (2015)	1	22	Avulsion (multi-lig)	7 d	Suture anchor (PFL + FCL repair)	27	Elite (judo)	Contact injury (hyperextension and varus load)	<ul style="list-style-type: none"> <li>“excellent knee ROM, 5°-145° and muscle strength”</li> </ul>	<ul style="list-style-type: none"> <li>0-3/52, immobilized in cast at 30° KF + NWB</li> <li>3-10/52, PWB in HKB</li> <li>10/52, FWB</li> </ul>
Riemer <sup>40</sup> (2014)	1	32	Avulsion	3 wk	Transosseous suture	NR	Recreational (soccer)	Hyperextension	<ul style="list-style-type: none"> <li>Postoperative wound infection requiring washout, debridement, and extended antibiotics*</li> <li>Neuropathic pain postop*</li> <li>NR. Pain-free RTS</li> </ul>	<ul style="list-style-type: none"> <li>0-6/52, PWB + immobilized at 0°-40° HKB</li> <li>2-4/52, HKB + passive FROM</li> </ul>
Geronikolakis <sup>20</sup> (2012)	1	41	Avulsion	2 d	Suture anchor	NR	Competitive (climber)	Hyperextension	<ul style="list-style-type: none"> <li>NR. Pain-free RTS</li> </ul>	<ul style="list-style-type: none"> <li>0-2/52, immobilized at 20° HKB</li> <li>2-6/52, PWB (20 kg) progression to FWB</li> <li>6/52, rehab with active flexion vs resistance</li> </ul>
Rehm <sup>39</sup> (2009)	1	27	Avulsion	Acute	Suture anchor	6	Recreational (soccer)	Hyperextension	<ul style="list-style-type: none"> <li>Isokinetic strength testing: rapid KF = 2.2% deficit, slower KF = 21.7% at 6 mo</li> </ul>	<ul style="list-style-type: none"> <li>0-1/52, immobilized in extension</li> <li>1-6/52, PWB in HKB</li> <li>6/52, active exercises</li> </ul>
Lempainen <sup>33</sup> (2007)	2	40	Avulsion	5 d	Suture anchor	2	Elite (ice hockey)	Noncontact; otherwise NR	<ul style="list-style-type: none"> <li>Excellent results; asymptomatic with a full RTS</li> </ul>	<ul style="list-style-type: none"> <li>0-2/52, NWB but no immobilization</li> <li>2-4/52, PWB + swimming/water training</li> <li>4/52, FWB, bicycling 3-6/52</li> <li>6-8/52, running</li> </ul>
Kusma <sup>30</sup> (2007)	1	43	Avulsion	Acute	Suture anchor	6	Recreational (soccer)	Hyperextension	<ul style="list-style-type: none"> <li>Maximum flexion and ER force showed no significant difference</li> </ul>	<ul style="list-style-type: none"> <li>0-6/52, immobilized at 30° KF</li> <li>6-12/52, active + passive ROM 0°-90° KF</li> <li>12/52, FROM with resistive exercises</li> </ul>
Werlich <sup>49</sup> (2001)	2	37	Avulsion	2 d	Transosseous suture	12	Recreational (football)	Sprinting	<ul style="list-style-type: none"> <li>Isokinetic testing: no significant difference</li> <li>Running analysis: good harmonious running pattern</li> </ul>	<ul style="list-style-type: none"> <li>0-6/52, immobilized</li> <li>6-12/52, PWB &amp; HKB at 25°-130° KF</li> </ul>
Pan <sup>37</sup> (2000)	1	33	Avulsion	4 mo	Transosseous suture	No RTS	Recreational (soccer)	Hyperextension (missed kick)	<ul style="list-style-type: none"> <li>Re-exploration for persistent discharging sinus (seroma) at 2 mo*</li> <li>No RTS but improved function for daily activities</li> </ul>	<ul style="list-style-type: none"> <li>0-2/52, immobilized at 80° KF in cast</li> <li>2-6/52, increasing 15° KF</li> <li>6/52, unrestricted ROM</li> </ul>
Sebastianelli <sup>42</sup> (1990)	1	21	Avulsion	Acute	Transosseous suture	6	Elite (collegiate football)	Extension + valgus load	<ul style="list-style-type: none"> <li>Patient successfully recovered his 36.6-m sprint (4.7 s)</li> </ul>	<ul style="list-style-type: none"> <li>0-4/52, immobilized at 60° KF</li> <li>4-6/52, 30°-60° arc</li> <li>6-8/52, FROM; 8/52, progressive resistive exercises</li> </ul>

<sup>a</sup>ER, external rotation; DVT, deep vein thrombosis; FCL, fibular collateral ligament; FROM, full ROM; FWB, full weightbearing; HKB, hinged knee brace; KF, knee flexion; multi-lig, multiple ligament injury; NFL, National Football League; NR, not reported; NWB, nonweight-bearing; postop, postoperatively; PFL, popliteofibular ligament; PWB, partial weightbearing; ROM, range of motion; RTS, return to play; SM, semitendinosus.

\*Complications.