Acute Adductor Muscle Injury

A Systematic Review on Diagnostic Imaging, Treatment, and Prevention

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Background: Controversies remain regarding the diagnosis, imaging, and treatment of acute adductor injuries in athletes.

Purpose: To investigate the diagnostic imaging, treatment, and prevention of acute adductor injuries based on the most recent and relevant scientific evidence.

Study Design: Systematic review; Level of evidence, 4.

Methods: The PubMed and Web of Science databases were searched according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to identify articles studying acute adductor injury in athletes. Inclusion criteria were original publication on acute adductor injury in amateur or professional athletes, level 1 to 4 evidence, mean patient age >15 years, and results presented as return-to-sport, pain, or functional outcomes. Quality assessment was performed with the CONSORT (Consolidated Standards of Reporting Trials) statement or the methodological index for non-randomized studies criteria. Articles were grouped as imaging, treatment, prevention focused, or mixed.

Results: A total of 30 studies published between 2001 and 2021 were selected, involving 594 male patients with a mean age 26.2 years (range, 16-68 years). The most frequent sports were soccer (62%), basketball (14%), futsal (6%), American football (3%), and ice hockey and handball (2%). Risk factors for acute adductor injury were previous acute groin injury, adductor weakness compared with the uninjured side, any injury in the previous season, and reduced rotational hip range of motion. The frequency of complete adductor muscle tears on magnetic resonance imaging was 21% to 25%. For complete adductor tears, the average time to return to play was 8.9 weeks in patients treated nonoperatively and 14.2 weeks for patients treated surgically. Greater stump retraction was observed in individuals treated surgically. Partial acute adductor tears were treated nonoperatively with physical therapy in all studies in the present systematic review. The average time to return to play was 1 to 6.9 weeks depending on the injury grade. The efficacy of adductor strengthening on preventing acute adductor tears has controversial results in the literature.

Conclusion: Athletes with partial adductor injuries returned to play 1 to 7 weeks after injury with physical therapy treatment. Nonoperative or surgical treatment is an acceptable option for complete adductor longus tendon tear.

Keywords: adductor injury; adductor longus muscle; groin pain; adductor pain; adductor avulsion in athletes; inguinal pain

Acute adductor injuries are frequent in sports activities requiring kicking or fast change of direction.[36,44,48] Adductor strain injuries represent half of the acute injuries around the hip joint in soccer players and 22% in National Basketball Association (NBA) players.[15,44] For elite soccer players, the incidence of acute adductor injuries has been estimated as 0.61 injuries per 1000 hours of exposure,[23] with a mean of 14 days' absence.[8] The incidence of acute adductor injuries in elite Australian rules football players is 3.2 new injuries per club per season, with a recurrence rate of 24%.[25] Comparable recurrence rates have been shown in soccer (18%),[8] collegiate ice hockey (22%),[7] and professional basketball (19%).[15]

Adduction of the hip joint is performed by the adductor longus muscle (ALM), adductor brevis, adductor minimus, adductor magnus, pectineus, gracilis, and obturator

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externus. The adductor muscles are predominantly innervated by the posterior division of the obturator nerve, arising from the second to fourth lumbar nerve roots.[42] The tibial portion of the sciatic nerve also contributes to the adductor innervation.[42] Most acute adductor lesions occur in the ALM,[27,32] which originates at the body of the pubis merging with the rectus abdominis insertion, composing the common adductor–rectus abdominis aponeurosis.[1,9] The ALM inserts into the middle third of the femoral linea aspera.[30]

A significant variability with regard to diagnostic imaging, treatment, and prevention of acute adductor injuries is observed among sports medicine practitioners.[6,17,29,30,32,47] Therefore, there is a need for an updated review on the diagnosis and management of acute adductor injuries in athletes. The aim of this systematic review is to investigate the diagnostic imaging, treatment, and prevention of acute adductor injuries based on the most recent and relevant scientific evidence.

METHODS

Literature Search

A thorough search was performed in 2 electronic databases (PubMed and Web of Science) to identify articles reporting the treatment of acute adductor injuries in athletes. The search was finalized in September 2021. Additional publications were identified by reviewing reference lists and citing articles via Google scholar. This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines[20] and was registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD42021244017). The search strategy used to search the PubMed database was the following:

All fields: (((adductor*) OR (groin)) OR (athletic pubalgia)) AND (((sprain)) OR (tear) OR (avulsion) OR (injury))

Study Selection

Two reviewers (S.G.F. and M.H.) independently screened the titles and abstracts of all citations identified by the literature search for relevance. Disagreements between the reviewers were solved by consensus. In sequence, the full text of the screened articles was assessed for eligibility by 1 reviewer (S.G.F.) according to the inclusion and exclusion criteria presented in Table 1. A full text was deemed *not found* after online search by the authors, a librarian-led search through an interlibrary loan system, and 2 unanswered emails sent to the corresponding author. When articles had the potential to satisfy inclusion criteria but were missing some critical data, we attempted to contact the authors for clarification and retrieval of the missing data. In case of ambiguous or missing data, the final decision to include the article was made by consensus among the 3 reviewers (S.G.F., M.H., and S.B.).

TABLE 1
Inclusion and Exclusion Criteria

Inclusion Criteria
• Original publication on diagnostic imaging, treatment, or prevention of acute adductor injury in athletes
• Level 1 to 4 evidence
• Mean age of patients >15 years
• Results presented as return to sport, pain scale, functional outcomes, or injury prevention
Exclusion Criteria
• Sample size ≤5 patients
• Nonathlete as predominant study population
• Chronic groin injuries or injuries not involving the adductor musculature
• Postoperative follow-up not reported or <3 months
• >30% of patients lost to follow-up
• Sample overlapped another study[a]
• Evidence level 5 studies, commentaries, or technique descriptions
• Epidemiologic study, systematic reviews

[a]Manuscripts with overlapping patients for assessment of different subjects (ie, diagnosis vs treatment vs prevention) were not excluded.

Quality Assessment

The level of evidence for each study was determined according to guidelines from the Centre for Evidence-Based Medicine (https://www.cebm.ox.ac.uk/resources/levels-of-evidence/oxford-centre-for-evidence-based-medicine-levels-of-evidence-march-2009). Prospective studies without a control group were considered a poor-quality cohort study and classified as level 4 evidence.

Observational studies were rated by 1 reviewer (S.G.F.) using criteria from the validated methodological index for non-randomized studies (MINORS).[41] The maximum possible MINORS score is 16 for noncomparative studies and 24 for comparative studies. Randomized controlled trials comparing adductor strength programs with normal training regimens were rated by 1 reviewer (S.G.F.) using a 25-point scale based on the CONSORT (Consolidated Standards of Reporting Trials) statement to assess reporting quality.[2,13]

Data Extraction

Studies were reviewed, and data were extracted and recorded into spreadsheets. Data were extracted from the Methods and Results sections, including tables and graphics. The year of publication, author, study design (randomized controlled trial, cohort study, case-control study, and case series), and study focus (diagnosis, imaging, treatment, prevention, or mixed) were recorded. The following information was extracted: number of patients, sex of patients, age, percentage of athletes, professional or amateur athlete, predominant sport, imaging studies

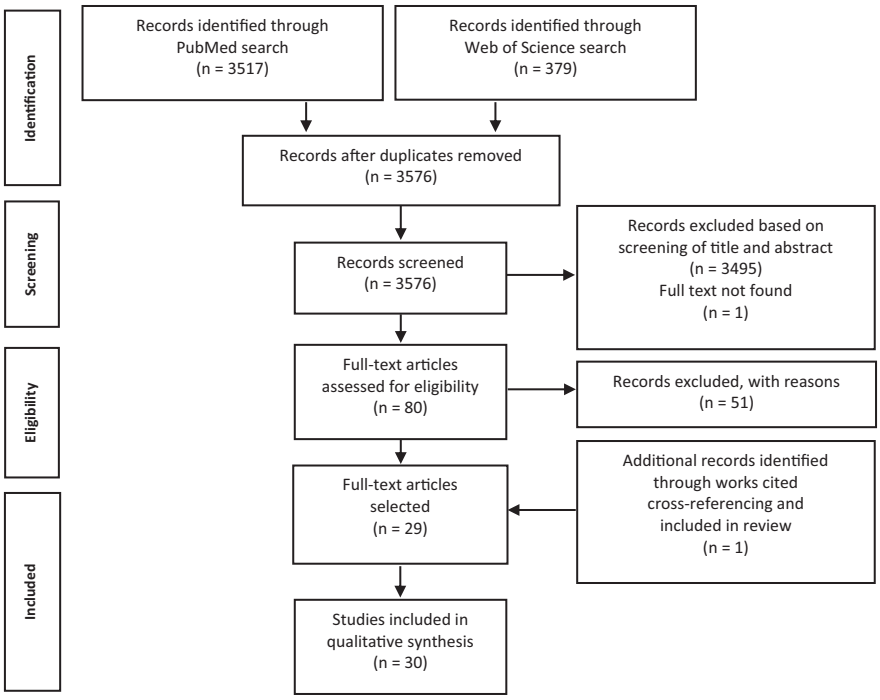

Figure 1. Study selection process using PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) flow diagram.[20]

performed, classification method, treatment or prevention methods, time to return to play, and rate of complications and reinjuries. Overlapping patients between different studies were considered when calculating the total number of patients included in this systematic review.

Statistical Analysis

All data were collected and analyzed using Microsoft Excel. The mean age, duration of symptoms, and follow-up were calculated for the entire sample by weighting each study's number of patients. Studies included in the systematic review were weighted according to sample size.

TABLE 2
Reasons for Exclusion After Full-Text Analysis

Reasons for Exclusion	No. of Studies
Review paper	22
Acute adductor injury not primary diagnosis	15
Sample size $\leq$5 patients	6
Epidemiologic study or sample overlapping another study	3
Book chapter, technique description, or infographic	3
Cadaveric study	1
Full text not found	1
Total	51

RESULTS

Study Selection

Figure 1 shows a flowchart of the study selection process. The literature search yielded a total of 3896 articles, with 3576 unique articles. A total of 80 articles were selected for full-text analysis: the full text of 1 article was not obtained, and 50 articles were excluded after full-text review (Table 2). One additional article was identified in a hand search, for a total of 30 articles in this systematic review. All articles were published between April 2001 and September 2021.

Quality of Studies

From the 30 articles selected, 22 were classified as level 4 evidence, 1 was classified as level 3, 5 were classified as level 2, and 2 randomized controlled trials were classified as level 1. The randomized trial comparing groin injuries in soccer players who completed an adductor-strengthening program[11] was considered an intermediate-quality trial, with 17 of 25 points according to CONSORT-based scoring.[2,13] The second randomized trial comparing an exercise program for prevention of groin injuries[12] was also considered an intermediate-quality trial, with 15 of 25 points according to CONSORT-based scoring.[2,13] The remaining 28 articles were noncomparative observational studies and scored on average 10.6 points (range, 6-13 points) according to the MINORS criteria[41] (Appendix Table A1, available in the online version of this article). The quality of the observational studies improved modestly with time, with a mean MINORS score of 10.2 for articles published between 2001 and 2015, 10.6 for articles from 2016 to 2019, and 10.9 for articles published from 2020 to 2021.

Patients

The total number of patients with acute adductor injury in the 30 articles was 594, of which 100% were male. The mean age of the patients was 26.2 years (range, 16-68 years). Of this total, 29 articles (580 patients) presented the distribution of the patients according to their sports activity. The most frequent sports were soccer (62% of the patients), basketball (14%), futsal (6%), American football (3%), ice hockey (2%), handball (2%), volleyball (1%), and rugby (1%). Less than 1% of patients played shotput, tennis, beach soccer, Australian rules football, taekwondo, decathlon, goalball, waterskiing, skiing, cricket, table tennis, ballet, golf, and figure skating.

Of the 30 articles, 14 studied magnetic resonance imaging (MRI) findings, 10 studied treatment modalities, and 11 investigated preventive measures for reducing acute adductor injuries.

Diagnostic Imaging

The MRI findings of acute adductor injuries were reported in 14 articles, including 296 patients, with 273 (92%) presenting injuries at the ALM (Table 3).[‖] One study reported the frequency of injury according to each specific muscle in a cohort with acute adductor injuries: ALM was the most affected muscle (72%), followed by adductor brevis (4%), obturator externus (4%), pectineus (2%), and adductor magnus muscle (1%).[37] The frequency of complete adductor muscle tear was reported as 21% by 1 author in a cohort including injuries in any adductor muscle.[37] In a cohort including only ALM tears, the frequency of complete tear was 25%.[27] The level of injury of the ALM in relation to the adductor origin was proximal in 40%, intermediate in 20%, and distal in 40%.

Three systems were used to classify acute adductor injuries based on MRI (Table 4). One study reported that 17% of patients with clinical diagnosis of adductor injury had a negative MRI after the clinical diagnosis of acute adductor injury.[40] One study reported that 75% of patients with acute ALM injury presented degenerative changes at the pubic symphysis on MRI.[27] Serner et al[33] found that 29% of patients had full tendon continuity, and 71% had partial tendon continuity on MRI at 1 year after injury.

Treatment

The treatment of acute adductor injuries was reported in 10 articles,[¶] including 216 patients (Table 5). For complete ALM tears, studies on the surgical management included injuries with greater stump retraction compared with studies using nonoperative treatment.[3,32] Treatment for complete ALM tears with physical therapy was reported in 3 studies including 36 individuals, and the average return to play was 8.9 weeks after injury.[32,33,47] Three studies on surgical treatment for complete ALM tears in 26 individuals reported an average return to play at 14.2 weeks after injury.[4,32,43] Best et al[3] and Schlegel et al[32] compared nonoperative versus surgical treatment for complete ALM tears with contemporary control groups. Best et al recommended surgery for patients with stump retraction $\geq$2 cm and demonstrated no difference in patient-related outcome measures for the surgical versus nonoperative groups. Best et al reported a return-to-play rate of 100% in both groups, although the return to play at previous level was different (86% for nonoperative treatment vs 57% for surgical treatment).[3] Schlegel et al also compared surgical versus nonoperative treatment for complete ALM tears and demonstrated 100% return to play and 100% return to play at previous level in both groups. Schlegel et al reported an average of 6.1 weeks to return to play for nonoperative treatment versus 12 weeks for surgical treatment, but the surgical group was composed of individuals with higher severity injuries (60% with retraction >3 cm in the surgical group vs 29% with retraction >3 cm in the nonoperative group).

Injury gap observed on MRI for complete ALM tears was studied as a prognostic factor in 2 studies.[27,33] Serner et al[33] reported no influence of stump retraction size on the results of nonoperative treatment for complete ALM tear, concluding that retraction length should not be used as a surgical indication. Pezzotta et al[27] reported that injury gap is a negative independent prognostic factor for return to play after ALM tear, and >2 cm of gap was associated with a minimum of 4 weeks to return to play. Degenerative changes and bone marrow edema at the pubic symphysis also delayed return to play according to Pezzotta et al.

Two studies presented the results of nonoperative treatment for incomplete adductor tears in 79 individuals.[27,40] Serner et al[40] reported an average of 1.9 weeks to achieve clinically pain-free status, 4.3 weeks from the injury to achieve completion of controlled sports training, and 6.9 weeks from the injury to return to full team training. Serner et al[40] reported no significant difference comparing injury grade 0, 1, or 2 for return to sport milestones. Pezzotta et al[27] reported that return to play for minor incomplete injuries was 1 to 2 weeks, while for moderate incomplete injuries it was 4 to 6 weeks. Three patients (15%) with a distal tendon lesion developed an intramuscular hematoma on average 1 week after injury, resulting in heterotopic ossification at 1 month after injury.[27] There was no study reporting surgical treatment for incomplete acute adductor tears.

The average recurrence rate for adductor injury was 5% (range, 0%-19%).[26,32,33,40,43,45,47] Patel et al[26] found a reinjury rate of 19% in NBA athletes who had any adductor muscle injury; despite this relatively high reccurrence, adductor injury did not significantly affect performance, game availability, or career longevity upon return. Serner et al[40] described a 7.4% reinjury rate within 1 year after completing treatment, and 5 of the 6 reinjuries occurred within the first 2 months of returning to full team training. Kicking-related injury and premature return to sport were associated with increased reinjury rates after complete ALM tear.[33,40]

[‖]References 3, 4, 19, 27, 31-33, 35-40, 47.
[¶]References 3, 4, 26, 27, 32, 34, 37, 43, 47.

TABLE 3
Characteristics of 14 Studies Reporting Magnetic Resonance Findings for Acute Adductor Injuries in Athletes[a]

Lead Author (Year)	Patients Studied, No.	Type of Injury Studied	Main Imaging Findings, Relevance
Serner (2021)[33]	16	ALM origin avulsion	All injuries were complete, classified as grade 3[b] on MRI, and treated nonoperatively. Mechanism of injury: change of direction (25%), reaching (25%), tackle (25%), kicking (19%), sprinting (6%). One year after injury, 29% of patients had full tendon continuity and 71% had partial tendon continuity; patients with partial continuity displayed minimal retraction (2 mm; range, 0-3 mm). One patient (6%) had heterotopic ossification at the ALM insertion 1 year after injury.
Serner (2020)[40]	50	Any adductor muscle	Patients with MRI grade 0, 1, or 2 injuries required an average of 10 supervised rehabilitation sessions; patients with grade 3 injuries required an average of 40 sessions. No significant differences in return to sport milestones for patients with grade 0, 1, or 2 injuries.
Serner (2020)[37]	81	Any adductor muscle	Injury grade on MRI[b]: 0 (17%), grade 1 (25%), grade 2 (37%), grade 3 (21%).[b] ALM was the most affected muscle (72%), followed by adductor brevis (4%), obturator externus (4%), pectineus (2%), and adductor magnus muscle (1%). Injury at bone-tendon junction on MRI was the most important predictor for longer return to sport.
Best (2020)[3]	14	ALM origin avulsion	Average ALM stump retraction of 2.15 cm (range, 0.5-6). Nonoperatively treated patients had mean stump retraction of 1.3 cm (0.5-1.8). Surgically treated patients had mean stump retraction of 3 cm (range, 2-6). Authors used stump retraction $\geq$2 cm as criterion to recommend surgery.
Schilders (2021)[31]	145	ALM origin avulsion	Association with rectus abdominis injury in 3.5%. Six patterns of PLAC injury identified.[c] The ALM was completely separated from the pyramidalis muscle in 56%, partially separated in 5%, and in continuity in 38% of the patients. Association with partial pectineus muscle avulsion in 33%.
Bharam (2018)[4]	6	ALM origin avulsion	Proximal tendon retraction average of 2.8 cm (range, 1.3-5).
Serner (2018)[39]	71	Any adductor muscle	Injury to only 1 muscle was observed in 65% of the patients. For the ALM injuries, 26% were at the proximal tendon insertion, 31% at the proximal musculotendinous junction, and 37% at the distal musculotendinous junction.
Pezzotta (2018)[27]	20	ALM	Degenerative changes at pubic symphysis in 75% of patients. 15% with distal injury developed heterotopic ossification. Injury location: proximal injury in 40%, distal in 40%, and intermediate in 20% of the patients. Injury at musculotendinous junction in 40%, intratendinous in 35%, and myofascial in 25% of the patients.
Serner (2017)[35]	52	Any adductor muscle	ALM was most affected muscle (65%), followed by pectineus (13%), adductor brevis (12%), gracilis (8%), and adductor magnus muscle (2%). ALM injury location: anteromedial (50%), anterolateral (32%), and both (17%). Injury grade[b]: grade 1 (53%), grade 2 (32%), grade 3 (15%). Main location of edema: central tendon (32%), indeterminable (28%), and proximal tendon (22%). Compared with acute lesions, nonacute lesions displayed a diffuse, lower-contrast intramuscular hyperintensity.
Mattiussi (2017)[19]	5	Perivascular ALM	ALM injuries close to the femoral vessels are difficult to be fully characterized on ultrasound due to posterior acoustic enhancement artifact related to the femoral vessels. MRI is recommended for assessment of adductor longus injuries around the femoral vessels.

(continued)

TABLE 3
(continued)

Lead Author (Year)	Patients Studied, No.	Type of Injury Studied	Main Imaging Findings, Relevance
Ueblacker (2016)[47]	6	Traumatic tendinous avulsions of the proximal ALM and significant tendon retraction from the pubic bone	All injuries studied had subtotal or total muscle tear or tendon avulsion. Mechanism of injury included overstretch while kicking (67%), sprinting (17%), and combined mechanisms (16%). Tendon retraction → mean of 21 ± 5 mm (range, 15-28). Size of defect proximal to the tendon stump → mean of 7.3 ± 4.5 cm (range, 2.1-14.8). MRI at 4 and 8 weeks after injury demonstrated significantly decreased defect/seroma with progressive reattachment of the tendon to the pubic bone. MRI at 12 weeks after injury demonstrated fully visible ALM tendon to its origin with no signs of retraction. All patients recovered full adductor muscle strength at 12.6 weeks (range, 10.7-15.7).
Serner (2016)[38]	81	Any adductor muscle	21% of athletes had negative MRI and the absence of palpation pain was best at predicting an MRI− result. Hip flexor clinical tests were poor at predicting and localizing MRI+ injuries in the hip flexors.
Serner (2015)[36]	73	Any adductor muscle	Most common mechanisms of injury included kicking (33%), change of direction (20%), stretch situations (17%), and sprinting/running (15%). Kicking leg was injured in 81% of kicking injuries, and the ALM was the most frequently injured muscle. Acute injury findings were negative in 22% of the MRI and 25% of the ultrasound examinations. Adductor injury location based on clinical diagnosis vs MRI findings: 72% were in the same location, 6% were in different locations, and 22% had negative imaging.
Schlegel (2009)[32]	19	ALM	Most common mechanism of injury included eccentric overload during change of direction (47%). Palpable defect was present with ≥3 cm of tendon retraction on MRI. MRI demonstrated ALM tear in 74% and ALM and adductor brevis tear in 26%. Tendon retraction from bone was <1 cm (11%), 1-3 cm (53%), and >3 cm (36%).

[a]The same lead author (Serner) was observed in 7 studies, with some having an overlapped recruitment period. All studies were included in this table, as the purpose and information presented are somewhat different between the studies. Articles with overlapping recruitment were not considered for purposes of calculating frequency and location of lesions as presented in the Results section. ALM, adductor longus muscle; FC, fibrocartilage; MRI, magnetic resonance imaging; PLAC, pyramidalis–anterior pubic ligament–ALM complex.
[b]See Table 4 for adductor muscle injury MRI grading in Serner et al[33,35,37,40].
[c]See Table 4 for PLAC injury grading in Schilders et al[31].

Prevention

Methods of preventing acute adductor injuries were reported in 11 studies, including 2522 patients (Table 6).[#] Seven studies were observational, and 4 studies were interventional, of which 2 were randomized controlled trials. Seven observational studies of acute adductor injuries in 1020 athletes reported an average incidence of 8.2%.[5,10,14,16,18,21,46] Risk factors for acute adductor injury were the following: previous acute groin injury,[10,12] adductor weakness compared with the uninjured side,[10,18,21,24,46] any injury in the previous season,[16] and reduced rotational hip range of motion.[14]

Adductor strengthening was shown to decrease incidence in 2 nonrandomized controlled trial interventional studies.[24,45] Núñez et al[24] reported an acute adductor injury rate of 0.07/1000 hours in athletes who completed an adductor and abductor strength program compared with 0.27/1000 hours in athletes who did not. For both groups, adductor injuries occurred when between-leg adductor strength asymmetry was >10% and the adductor-to-abductor power ratios were <0.9.[24] Tyler et al[45] implemented an adductor strength program for at-risk athletes whose adductor-to-abductor strength ratio was <80% and reported a significant decrease in the incidence of adductor injuries compared with the previous season in at-risk athletes (9% vs 38%).

Two randomized controlled trials investigated the effect of adductor-strengthening programs to prevent groin

[#]References 5, 10-12, 14, 16, 18, 21, 24, 45, 46

TABLE 4
Classification Systems for Acute Adductor Injury

Lead Author (Year)	Classification
Serner (2017)[35]	Muscle injury classification[a]: • Grade 0, no acute injury findings (negative imaging) • Grade 1, diffuse intramuscular hyperintensity (edema) without any visible structural disruption • Grade 2, edema collection indicating partial structural muscle fiber or intramuscular tendon disruption (partial tear) • Grade 3, complete musculotendinous disruption/tear or avulsion from the tendinous attachment
Schilders (2021)[31]	Pyramidalis–anterior pubic ligament–adductor longus complex injury grading: • Type 1, complete fibrocartilage (FC) avulsion–pyramidalis separated from adductor longus–intact pectineus • Type 2, complete FC avulsion–pyramidalis separated from adductor longus–partial pectineus tear • Type 3, complete FC avulsion–pyramidalis connected to adductor longus–intact pectineus • Type 4, complete FC avulsion–pyramidalis connected to adductor longus–partial pectineus tear • Type 5, complete FC avulsion–pyramidalis partially separated from adductor longus–partial pectineus tear • Type 6, partial FC avulsion–pyramidalis connected to adductor longus–intact pectineus
Pezzotta (2018)[27]	Munich consensus[b]: • Type 3A: Minor partial muscle tear • Type 3B: Moderate partial muscle tear • Type 4: (Sub)total muscle tear or tendon avulsion British athletics muscle injury classification[c]: • Grade 1: small tear <1 cm and high signal change of craniocaudal length of <5 cm • Grade 2: moderate tear 1 to 5 cm and high signal change of craniocaudal length of 5 to 15 cm • Grade 3: extensive tear >5 cm and high signal change of craniocaudal length of >15 cm • Grade 4: full-thickness muscle/tendon tear with retraction

[a]Classification originally reported by Zarins and Ctulio.[49]
[b]Classification originally reported by Mueller-Wohlfahrt et al.[22]
[c]Classification originally reported by Pollock et al.[28]

TABLE 5
Characteristics of 10 Studies Reporting Results of Treatment for Acute Adductor Injuries in Athletes[a]

Lead Author (Year)	Patients Studied, No.	Treatment	Type of Injury Treated	Mean RTS, wk	Reinjury	Treatment Findings, Relevance
Serner (2021)[33]	16	Nonoperative	ALM origin avulsion	10 (range, 5-30)	7%	Active exercises with independent progression of basic exercises, running, and change-of-direction drills. Controlled sports training phase. Symmetry on eccentric adduction supine strength: 79% at completion of controlled sports training and 93% at 1 year after injury. Symmetry on bent-knee fall-out abduction range of motion: 36% on initial examination and 100% at 1 year after injury. HAGOS score at 1 year after injury: 100 for all subscales. 7% had intermittent adductor-related groin pain considered related to the previous injury.
Serner (2021)[34]	61	Nonoperative	Any adductor muscle tear, 21% with complete tear	3.4 (range, 1-30)	NR	Partial injuries: median 13 days (range, 6-44) to be clinically pain-free, median 17 days (range, 9-64) to return to full team training. Complete tear: median 55 days (range, 27-166) to be clinically pain-free, median 68 days (range, 32-212) to return to full team training.
Patel (2020)[26]	55	Mixed: nonoperative (95%), surgical (5%)	Any adductor muscle injury	2.41 (SD, ± 2.91)	19%	All patients were professional basketball players. Guards were injured more frequently than forwards or centers. After treatment and return to sport, acute adductor injury did not affect player performance or game availability or career longevity. Return to play after first-time adductor strain (n = 51): mean 6.4 games or 2 weeks missed. Return to play after first-time adductor tear (n = 4): median 11 games or 3.5 weeks missed. Authors report a median of 12 weeks for return to play in 3 cases surgically treated. Assuming these 3 cases were tears, there is an inconsistency with the median of 3.5 weeks reported for all 4 tears.
Best (2020)[3]	14	Mixed: nonoperative (50%), surgical (50%)	Adductor longus origin avulsion	NA	NR	Authors used stump retraction ≥2 cm as a criterion to recommend surgery. Nonoperative: crutches 2 to 3 weeks, normal activity if symptom-free, return to sports at minimum 6 weeks. Surgical: anchor refixation repair. No significant differences between nonoperative and operative groups in terms of patient-related outcomes (modified Hip Harris Score, Hip Outcome Score, Activities of Daily Living subscale, or Sports subscale). Non–statistically significant difference in patient-reported postinjury level of sport compared with preinjury: nonoperative group mean of 93% vs operative group mean of 99%.

(continued)

TABLE 5
(continued)

Lead Author (Year)	Patients Studied, No.	Treatment	Type of Injury Treated	Mean RTS, wk	Reinjury	Treatment Findings, Relevance
Serner (2020)[40]	81	Nonoperative	Any adductor muscle, partial or complete tear	Grades 0-2 (partial tear): 2.6 (range, 0.7-8) Grade 3 (complete tear): 11 (range, 5-32)	8%	RTS milestones comparison: (1) Clinically pain-free: 2 weeks for grade 0 to 2 injury (range, 1-6); 8 weeks for grade 3 (range, 3-24). (2) Completion of controlled sports training: 2 weeks for grades 0 to 2 (range, 1-9); 10 weeks for grade 3 (range, 5-30). (3) Return to full team training: 2 weeks for grades 0 to 2 (range, 1-8); 11 weeks for grade 3 (range, 5-32). Hip abduction ROM symmetry on initial examination mean = 82% ± 25%; after completing controlled sports training, mean = 101% ± 7%. Eccentric adduction strength in side-lying position symmetry on initial examination mean = 71% ± 23%; after completing controlled sports training, mean = 97% ± 13%. Abduction/adduction ratio (for the injured leg) on initial examination mean = 0.85 ± 0.29; after completing controlled sports training, mean = 1.18 ± 0.23.
Pezzotta (2018)[27]	20	Nonoperative	ALM, 25% with complete tear	Minor lesions: 1-2 Moderate lesions: 4-6 Complete lesions: >6	NR	Injury gap extension on MRI correlates with time to return to play. Munich consensus and BAMIC scores had a significant correlation with RTP (Pearson coefficient = 0.974, $P < .0001$; and .958, $P < .0001$, respectively). Three patients (15%) with a distal tendon lesion developed an intramuscular hematoma (mean time of 1 week after injury) → they each developed myositis ossificans in a mean time of 1 month after injury. Three patients (15%) with a proximal tendon lesion developed a fibrous scar (mean time 3 months after injury).
Bharam (2018)[4]	6	Surgical	ALM origin avulsion >1 cm of retraction	19 (range, 12 to 32)	NR	Surgical reattachment of proximal adductor avulsion injuries using a suture anchor technique. A surgical indication included proximal adductor avulsion with retraction >1 cm on MRI: mean retraction was 2.8 cm (range, 1.3-5). Surgery performed on average 2.7 weeks after injury (range, 1-5). Rehab summary: partial weightbearing for 2 weeks; ROM limited to neutral extension and abduction for 4 weeks; isometric strengthening began at 5 weeks; progressive adductor strengthening began at 6 weeks; sport-specific drills began >6 weeks once adductor strength symmetry was comparable and pain-free resisted groin adduction. RTS criteria included no pain with manual muscle testing and symmetry on adductor strength. RTS mean was 19 weeks (range, 12-32); 5 patients (83%) returned at preinjury level of sport, 1 patient (17%) returned at a lower level of competition. Manual testing at 12 weeks postoperatively demonstrated no pain and grade 5/5 adduction strength symmetrical to noninjured side. One patient (17%) had complications of wound dehiscence and required re-exploration for suture granuloma removal.
Ueblacker (2016)[47]	6	Nonoperative	ALM origin avulsion >1 cm of retraction	13 (range, 11-16)	0%	50% of patients had previous complaints of groin pain before avulsion. Mean stump retraction = 2.1 cm (range, 1.5-2.8). Rehab summary: 1 to 3 weeks hip ROM limited to 10°-0°-10°, no active abduction/stretching, no massage on injury site to avoid calcification, lymphatic drainage; 4 to 5 weeks ROM limited to 20°-0°-20°, body weight exercises, cycling, aquajogging; 6 weeks free ROM, running, endurance training, manual stretching; 7 weeks strengthening exercises, tonisation of adductor longus, coordination exercises; 8 to 10 weeks intense running, sport-specific training; 10+ weeks sprints, multidirectional running, return to team. Symmetric hip ROM was reached at 8 weeks; full adductor power was reached at 13 weeks (range, 11-16) with normal strength. All patients were competing at preinjury level at most recent follow-up (18 months; range, 3-52).
Tansey (2015)[43]	15	Surgical	Adductor origin/ rectus abdominis complex, complete tear	13 (range, 10-21)	0%	Tension-free reattachment of the avulsed tendons using suture anchors. Surgery was performed a mean of 2.5 weeks after injury (range, 1-5). Rehab summary: protected toe-touch weightbearing for 2 weeks; gradual progression of a strength-training program thereafter. Seven patients (47%) required abdominal wall reinforcement with synthetic mesh due to findings of weakness of abdominal wall. Four patients (27%) had postoperative nerve symptoms at 12 weeks but did not prevent RTS. One patient (7%) developed early superficial wound infection treated with antibiotics. RTS was 13 weeks (range, 10-21) with 100% returning at preinjury level; adductor squeeze test was negative for pain in both flexion and extension in all patients before RTS.
Schlegel (2009)[32]	19	Mixed: nonoperative (74%), surgical (26%)	ALM origin avulsion	Nonoperative: 6 (range, 3-12) Surgical: 12 (range, 10-16)	0%	In National Football League involving multiple providers. Nine patients (47%) had adductor longus ruptures that occurred due to eccentric overload while changing direction. Nonoperative protocol: week 1 included anti-inflammatory medications, ice/heat, e-stim, nonresisted stationary bike, pool walking, and stretching; week 2 included core strengthening exercises, light plyometrics, treadmill running; weeks 3 to 6 included heavier running and strengthening of the groin, gradual position-specific drills. Surgical: ALM origin repair using suture anchors; a concomitant hernia repair was performed in 1 patient. Postoperative protocol: protected weightbearing for 2 to 4 weeks; strength exercises at 6 to 8 weeks. One patient (5%) developed a draining wound and heterotopic ossification. RTP was twice as long for operative group vs nonoperative. However, the surgical group was composed of individuals with higher severity injuries (60% with retraction >3 cm in the surgical group vs 29% with retraction >3 cm in the nonoperative group).

[a]The same lead author (Serner) was observed in 3 studies, with some having an overlapped recruitment period. All studies were included in this table, as the purpose and information presented are somewhat different between the studies. Articles with overlapping on recruitment were not considered for the summary presented in the Results section. ALM, adductor longus muscle; BAMIC, British Athletics Muscle Injury Classification; HAGOS, Copenhagen Hip and Groin Outcome Score; MRI, magnetic resonance imaging; NA, not applicable; NR, not reported; ROM, range of motion; RTP, return to play; RTS, return to sport.

TABLE 6
Characteristics of 11 Studies on Prevention of Acute Adductor Injuries in Athletes[a]

Lead Author (Year)	Interventional vs Observational Study	Patients Studied, No.	Population	Incidence of Adductor Injuries	Main Prevention Findings, Relevance
Markovic (2020)[18]	Observational	45	Professional soccer players	16%	Professional athletes with adductor weakness and/or strength asymmetry had increased incidence of adductor injuries. Ten groin injuries occurred (7 adductor, 2 pubic symphysis, 1 iliopsoas); mean 14 days absence (range, 5-27 days). Injured players had lower preseason isometric adductor strength (2.65 ± 1.06 N•m/kg) vs uninjured players (3.44 ± 0.54 N•m/kg) (P = .002). Injured players had higher between-limb adductor strength asymmetry (16.82% ± 10.61%) vs uninjured players (9.95% ± 6.88%) (P = .018). Within the injured group, isometric adductor strength was weaker on the injured side (2.43 N•m/kg) compared with the contralateral unaffected side (2.87 N•m/kg) (P < .001).
Núñez (2020)[24]	Interventional: abductor and adductor strengthening	48	Professional soccer players	Control group: 0.27 injuries/1000 h Intervention group: 0.07 injuries/1000 h	Players completed ADD/ABD strength training 2×/week for 8 weeks preseason, then 1×/week during the 37-week season; team A trained with a reduced number of sets for the higher-power output leg, while team B trained with an increased number of sets for the lower-power output leg. Adductor injury rate for team A = 0.09 ± 0.02 (during training) and 0.18 ± 0.03 (during matches); team B = 0.0 (during training) and 0.07 (during matches); team A averaged 11.33 ± 2.4 days missed; team B averaged 6.0 ± 0.0 days missed. In both programs, adductor injuries occurred around the time the between-leg adductor strength asymmetry was >10% and ADD/ABD power ratios were <0.9.
Moreno-Pérez (2019)[21]	Observational	71	Professional soccer players	17%	Adductor weakness and lower force related to body mass are a predictor of groin injuries. Injured players had lower isometric adductor strength (5.40 ± 1.27 N/kg) vs uninjured players (7.71 ± 0.89 N/kg) (d = 1.88; 90% CL, –2.37 to 1.39). Injured players had lower isometric adductor strength (429.8 ± 100 N) vs uninjured players (564 ± 58.7 N) (d = 1.58; 90% CL, –2.08 to 1.07). Force relative to body mass better predicted groin injuries (OR = 6.8; 2.699-17.129) compared with maximal isometric adductor strength alone (OR = 1.005; 1.001-1.009).
Harøy (2019)[11]	Interventional: adductor strengthening	247 (intervention) 242 (control)	Amateur soccer players	Control group: 21.3% weekly prevalence Intervention group: 13.5% average weekly prevalence of all groin injuries = 13.5% (intervention group) and 21.3% (control group)	Players completed the CA exercise program 2× to 3×/week for 6 weeks preseason (3-15 repetitions per side), then 1×/week during the 28-week season (12-15 repetitions per side). Players completed, on average, 70% of the exercise program protocol during the preseason and regular season; short, simple exercise programs that effectively target the adductors may improve compliance. Mean weekly prevalence of all groin injuries = 13.5% (intervention group) and 21.3% (control group). Mean weekly prevalence of substantial groin injuries (moderate, severe, or complete inability to participate) = 5.7% (intervention group) and 8.0% (control group). Adductor strength programs, specifically using the CA exercise, reduces the prevalence of groin injuries in male soccer players.
Langhout (2018)[16]	Observational	171	Professional soccer players	9%	General injury sustained in the previous season (ankle, knee, thigh, shoulder; median 9-week time loss) was a risk factor for groin injury (hazard ratio, 5.1; 95% CI, 1.1-14.6; P = .003). Twenty-four groin injuries occurred in 18 players (16 adductor related, 5 pubic, 1 iliopsoas, 1 inguinal, 1 hip); 8 minor injuries (<7 days), 10 moderate (8-28 days), 6 severe (>28 days); total groin injury incidence was 2.6 injuries/1000 h for matches and 0.2 injuries/1000 h for training; median time loss = 13 days.
Crow (2010)[5]	Observational	77	Professional Australian football players	16%	Preseason bilateral adductor strength (N) was measured and correlated with adductor injuries. Twelve groin injuries occurred (unspecified locations); mean onset of injury occurred at 3.58 ± 1.88 weeks; injured players saw a significant decrease from baseline in mean hip adductor strength in the week the injury occurred (mean, 11.75% ± 2.50%) and the preceding week (mean, 5.83% ± 5.16%).

(continued)

TABLE 6
(continued)

Lead Author (Year)	Interventional vs Observational Study	Patients Studied, No.	Population	Incidence of Adductor Injuries	Main Prevention Findings, Relevance
Engebretsen (2010)[10]	Observational	508	Amateur soccer players	4%	Adductor strength and history of previous injury were assessed at preseason. Previous acute groin injury (OR, 2.60) and weak adductor muscles (OR, 4.28) were associated with increased risk of groin injuries. Acute time-loss injuries revealed that a faster 40-m sprint test (adjusted OR, 2.03) and painful testing of the abdominal rectus muscle (adjusted OR, 15.5) as significant risk factors for adductor injury. Age and countermovement jump test (a fast twitch, explosive muscle test) were player-dependent factors associated with groin injury.
Hölmich (2010)[12]	Interventional: adductor strengthening	477 (intervention) 430 (control)	Amateur soccer players	Control group: hazard ratio = 1 Intervention group: hazard ratio = 0.69	Cluster randomized trial, 27 clubs were randomized to an exercise program and 28 clubs to a control group training as usual. The intervention program consisted of 6 exercises, including strengthening (concentric and eccentric), coordination, and core stability exercises for the muscles related to the pelvis. Exercise program did not reduce time to first injury compared with control (P = .18). Previous groin injury doubles the hazard of developing a new groin injury, and playing at a higher level nearly triples the hazard.
Ibrahim (2007)[14]	Observational	101	Professional soccer players	8%	Preseason internal and external rotation hip ROM was compared with occurrence of adductor injury. Injured athletes had a significantly lower preseason hip ROM vs uninjured athletes (44.7° vs 53.7°; injured dominant leg, P = .03; injured nondominant leg, P = .04).
Tyler (2002)[45]	Interventional: adductor strengthening	58	Professional hockey players	5%	Preseason bilateral hip adductor and abductor strength was measured and any athlete with an adductor-to-abductor strength ratio <80% was placed in the exercise program. Three of 33 (9%) at-risk players (<80% adductor-to-abductor strength ratio) had an adductor strain during the intervention, compared with 8 of 21 (38%) at-risk players during the preintervention seasons (P < .05).
Tyler (2001)[46]	Observational	47	Professional hockey players	17%	Preseason bilateral hip flexion, adductor, and abductor strength were compared in athletes with and without adductor injury. Injured athletes had a mean of 18% lower hip adduction strength vs uninjured athletes (P = .021). Hip adductor-to-abductor strength ratio was significantly different between injured vs uninjured athletes (78% in injured vs 95% in uninjured; P = .038). No significant difference was seen between preseason hip adductor ROM in injured vs uninjured athletes (46.3° ± 10.3° vs 45.8° ± 11.0°; P = .92).

[a]ABD, abductor; ADD, adductor; CA, Copenhagen adduction; CL, confidence limit; OR, odds ratio; ROM, range of motion.

injuries in amateur soccer players.[11,12] Both studies did not present the specific rates of acute adductor injuries, instead presenting the overall groin injury rate in their results. Hölmich et al[12] reported no significant difference in the hazard ratio (HR) for groin injuries in the control group (HR, 1; n = 430) versus intervention group (HR, 0.69; n = 477). The second randomized controlled trial by Harøy et al[11] compared the prevalence of all groin injuries between an adductor-strengthening intervention group and a control group. They reported a higher average weekly prevalence of groin injuries in the control group (21.3%, n = 242; 95% CI, 20.0%-22.6%) versus the intervention group (13.5%, n = 247; 95% CI, 12.3%-14.7%).[11] Specifically for injuries causing moderate, severe, or complete inability to participate, the weekly prevalence was 8.0% in the control group versus 5.7% in the intervention group.[11]

DISCUSSION

The present systematic review included studies on surgical and nonoperative treatment for complete ALM tears. Although the return-to-play timeline was shorter for nonoperative treatment (8.9 weeks after injury[32,33,47]) in comparison with surgical treatment (14.2 weeks after injury[4,32,43]), the individuals treated surgically had greater stump retraction compared with individuals treated nonoperatively.[3,32] Two studies used the injury gap as a criterion for surgery indication in complete ALM tears.[3,4]

Bharam et al[4] recommended surgical treatment when retraction on MRI was >1 cm and Best et al[3] when the retraction was ≥2 cm. Contrasting results are published regarding the injury gap as a negative prognostic factor.[27,33] While Serner et al[33] reported no influence of injury gap on results of nonoperative treatment for complete ALM tears, Pezzotta et al[27] found that >2-cm gap was associated with a delayed return to play.

Partial acute adductor tears were treated nonoperatively with physical therapy in all studies in the present systematic review. The average return to play ranged from 1 to 6.9 weeks depending on the injury grade.[27,40] Despite the increasing utilization of platelet-rich plasma injections for treatment of tendon injuries in sports medicine, there was no study on the results of injections for treatment of acute adductor injuries.

Magnetic resonance imaging was the preferred complementary testing for the diagnosis and classification of an acute adductor injury. The ALM was affected in 72% of acute adductor injuries in athletes.[37] Complete adductor muscle tears were observed in 21% to 25% according to 2 studies.[27,40] MRI has also been helpful in assessing the tendon continuity after treatment. Serner et al[33] reported that 71% of the individuals with complete ALM tear treated nonoperatively demonstrated a partial tendon continuity after injury. This finding was not corroborated by Ueblacker et al,[47] who observed fully visible ALM tendon to its origin without evidence of retraction at 12 weeks after injury in individuals with a complete ALM tear and tendon retraction at the time of injury. The study by Ueblacker et al presents MRI images describing no signs of ALM tendon retraction at 12 weeks after nonoperative treatment, but the authors of the present study observed retraction of the ALM tendon in the presented images. Other authors described fibrotic tissue to be a "neo-tendon" and considered this a sign of reattachment, even if the original tendon was retracted distally.[33] Despite the similarity between the fibrotic tissue (pseudotendon) and the native adductor tendon on MRI, the histologic and mechanical properties of the adductor pseudotendon have not been tested.

Researchers have not been consistent with classification methods for acute adductor injury, and 4 different classification methods are used (Table 4).[27,31,35] Most authors use a general muscle injury classification for the acute adductor injury ranging from 0 (clinical diagnosis, negative imaging) to 3 (complete musculotendinous disruption/tear or avulsion from the tendinous attachment).[35] The Munich consensus and British athletics muscle injury classification have also been used to classify acute adductor injuries.[27] Schilders et al[31] reported a detailed classification focusing on the pyramidalis–anterior pubic ligament–adductor longus complex to grade acute adductor injuries. This classification has not been used by any additional investigator and has not been correlated with treatment results.[31]

The most studied intervention for prevention of acute adductor injuries was preseason or in-season adductor strengthening.[11,12,24,45] Two randomized controlled trials presented contrasting results on the effectiveness of adductor strengthening to prevent acute adductor injuries. Hölmich et al[12] observed no significant difference in groin injuries comparing the control group (no adductor strengthening) versus intervention group (adductor strengthening). However, Harøy et al[11] found adductor strengthening to decrease the risk of acute groin injuries. A major limitation of both randomized controlled trials is that the authors did not present the specific rates of acute adductor injuries, instead presenting the overall groin injury rate in general. Two nonrandomized controlled trials reported a 3 times lower adductor injury rate for athletes who completed an adductor-strengthening program.[24,45] Adductor strengthening may be particularly beneficial for athletes with increased risk of acute adductor injury, including those with previous acute groin injury,[10,12] adductor weakness compared with the uninjured side,[10,18,21,24,46] any injury in the previous season,[16] and reduced rotational hip range of motion.[14]

The number of studies on the imaging, treatment, or prevention of acute adductor injuries in athletes has consistently increased in the past 2 decades. From the 30 articles reviewed, 10 were published between 2001 and 2016, 11 between 2016 and 2019, and 7 between 2020 and 2021. Only 2 (7%) were randomized controlled trials: 2 intermediate-quality trials comparing groin injuries in soccer players who completed adductor-strengthening programs.[11,12] Although both trials were published in the past decade, the quality of the observational studies improved modestly with time, with a mean MINORS score[41] of 10.2 for articles published between 2001 and 2015, 10.6 for articles published from 2016 to 2019, and 10.9 for articles published from 2020 to 2021.

The current systematic review has a number of limitations. First, the leading author was the same in 47% of the studies included in the imaging section and 30% of studies included in the treatment section. This demonstrates his dedication to understanding this pathology and his contribution to the field. However, the extrapolation to other populations and practitioners is limited, especially considering the author's expertise with treating acute adductor injuries nonoperatively. Second, the treatment section did not include any randomized controlled trials, and the power of the findings is directly proportional to the quality of the studies. Third, as with all systematic reviews, it is possible that relevant articles or patient populations were not identified with our search criteria.

CONCLUSION

Risk factors for acute adductor injury include previous acute groin injury, adductor weakness, any injury in the previous season, and reduced rotational hip range of motion. Athletes with partial adductor injuries return to play in 1 to 7 weeks after injury with physical therapy treatment. Nonoperative or surgical treatment is an acceptable option for complete adductor longus tendon tear.

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