One-Year Clinical and Imaging Follow-up After Exercise-Based Treatment for Acute Complete Adductor Longus Tendon Avulsions in Athletes

A Prospective Case Series

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Background: Complete avulsions of the adductor longus tendon are serious injuries, yet we have few data to inform clinical decisions on management. Previous studies are limited by a lack of detailed follow-up.

Purpose: To describe detailed clinical and imaging measures 1 year after complete proximal adductor longus avulsion injuries in athletes who received exercise-based treatment.

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

Methods: A total of 16 adult male competitive athletes were included in this study <7 days after an acute adductor longus tendon avulsion injury. All athletes were advised to complete a supervised standardized criterion-based rehabilitation protocol. Standardized clinical examination, a modified Copenhagen Hip and Groin Outcome Score (HAGOS), the Oslo Sports Trauma Research Centre Overuse Injury Questionnaire (OSTRC-O), and detailed magnetic resonance imaging (MRI) assessment were performed after inclusion, on the day of completion of the treatment protocol (return to sport), and at 1-year follow-up after injury.

Results: One player was lost to follow-up. Median return-to-sport time was 69 days (interquartile range [IQR], 62-84). One player had an early reinjury and performed an additional rehabilitation period. One-year follow-up was completed a median from 405 days (IQR, 372-540) after injury. The median HAGOS score was 100 for all subscales (IQRs from 85-100 to 100-100), and the median OSTRC-O score was 0 (IQR, 0-0). The median range of motion symmetry was 100% (IQR, 97%-130%) for the bent-knee fall-out test and 102% (IQR, 99%-105%) for the side-lying abduction test. Side-lying eccentric adduction strength symmetry was 92% ± 13% (mean ± SD), and median supine eccentric adduction strength symmetry was 93% (IQR, 89%-105%). MRI results at 1-year follow-up showed that from the original complete discontinuity in all cases, 10 athletes (71%) had partial tendon continuity, and 4 (29%) had complete tendon continuity.

Conclusion: Nonsurgically treated athletes with a complete acute adductor longus avulsion returned to sport in 2 to 3 months. At the 1-year follow-up after injury, athletes had high self-reported function, no performance limitations, normal adductor strength and range of motion, and signs of partial or full tendon continuity as shown on MRI. This indicates that the primary treatment for athletes with acute adductor longus tendon avulsions should be nonsurgical as the time to return to sport is short, there are good long-term results, and there is no risk of surgical complications.

Keywords: groin pain; hip/pelvis/thigh; muscle injuries; general sports trauma; physical therapy/rehabilitation; imaging; magnetic resonance; clinical assessment/grading scales

Complete avulsions of the adductor longus tendon are debilitating injuries in athletes.[22] A high index of clinical suspicion is important when athletes have acute onset of groin pain at the proximal insertion of the adductor muscles. Clinical examination tests have high ability to detect or rule out a complete adductor longus avulsion as shown on magnetic resonance imaging (MRI). If a palpable defect of the adductor longus tendon is felt in the proximal medial thigh, clinicians can be confident in diagnosing an avulsion. The absence of pain during passive adductor stretch and the absence of palpation pain on the proximal adductor longus insertion can be used to confidently rule out an acute complete adductor longus tendon avulsion.[17] MRI is considered the gold standard for use in the

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diagnosis of avulsion injuries, and detailed MRI variations of avulsion injuries are reported to potentially influence treatment decisions.[14]

There is scant data to inform clinical decision making on management and whether to choose a surgical reattachment or a nonsurgical exercise-based treatment approach of these injuries. Both treatment options appear to have good return-to-sport (RTS) outcomes,[1,2,15,22,24,27] but there are no randomized controlled trials comparing these options.[8] Previous small case series in athletes indicate that using an exercise-based approach results in a faster RTS time than surgical reattachment, with mean RTS times of 6 to 13 weeks[15,27] as compared with 12 to 21 weeks, respectively.[2,15,24] These studies are, however, limited by a lack of details on the treatment (eg, descriptions of the rehabilitation protocols) and by short follow-up at and after RTS, such as information on self-perceived function, adductor muscle strength and flexibility, structural healing, as well as reinjury risk. These may be important treatment decision modifiers.

Our aim was to describe detailed clinical and imaging measures 1 year after complete proximal adductor longus avulsions in male athletes who received standardized (nonsurgical) exercise-based treatment.

METHODS

Participants

This is a follow-up study of a subgroup of athletes from a larger prospective cohort of athletes with acute groin injuries.[22] Athletes were consecutively included over 4 sports seasons (August 2013 to June 2017) at an orthopaedic and sports medicine hospital in Qatar. For this study, additional clinical and imaging follow-up examinations were scheduled 1 year after injury. General inclusion criteria were male athletes aged 18 to 40 years who participated in competitive sports. Athletes had to present at the hospital within 7 days of an acute onset of groin pain that occurred during sport. Exclusion criteria were a gradual onset or exacerbation of ongoing groin pain, acute groin pain not involving the adductor muscles on clinical examination, clinical signs or symptoms of prostatitis or urinary tract infection, or other known coexisting chronic diseases (eg, significant hip osteoarthritis). In this study, we included only the athletes who had a proximal MRI grade 3 adductor longus injury, signifying a complete tear/avulsion.[21]

Ethical approval was granted by the institutional review boards of the Shafallah Medical Genetics Center and the Anti-Doping Lab Qatar (projects 2012-013 and EXT2014000004), and informed consent was acquired from all athletes before inclusion.

Patient Characteristics and Patient-Reported Outcome Measures

Athlete characteristics, such as age, height, weight, type of sport, and a modified Copenhagen Hip and Groin Outcome Score (HAGOS) questionnaire,[26] were recorded as previously described.[22] The modification of the HAGOS was that we initially requested answers related to the period "since injury," instead of the "past week." The standard HAGOS questionnaire was completed at RTS and at 1-year follow-up. At 1-year follow-up, the Oslo Sports Trauma Research Centre Overuse Injury Questionnaire (OSTRC-O) on groin problems was also completed.[7]

Clinical Examination

Standardized clinical examination tests were performed by a physical therapist (A.S.) following inclusion into the study, on the day of completion of the treatment protocol, and at the 1-year follow-up. The physical therapist was blinded to imaging findings from the respective time point. The clinical pain provocation tests consisted of palpation, stretch, and resistance tests and have previously been published in detail.[20] The physical therapist also conducted a passive hip abduction range of motion test with the patient in a side-lying position and the bent-knee fall-out test,[10] as well as eccentric strength in side-lying hip adduction and abduction tests.[22] Furthermore, eccentric adduction strength was tested supine in an outer-range position[22] on the day of completion of the treatment protocol and at 1-year follow-up. This test was considered too strenuous to be included in the initial examination. Limb symmetry, in percentage, and side-lying eccentric adduction/abduction strength ratio were calculated. Intra- and intertester reproducibility of these tests was good to excellent (intraclass correlation coefficients, 0.66-0.92; SEM, 7%-14%).[11,22]

MRI Assessment

An MRI examination was performed initially after the injury, after completion of rehabilitation, and at 1 year

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after injury. MRI was performed on a 1.5-T magnet system (Magnetom Espree; Siemens) using a body matrix coil, as previously published in detail.[19] Eight sequences were performed: 1 sagittal (fat-suppressed, proton-density weighted), 2 coronal (T1-weighted and short tau inversion recovery), 3 axial (T1-weighted; fat-suppressed, proton-density weighted; fat-suppressed, T2-weighted), and 2 axial oblique (fat-suppressed, proton-density weighted; fat-suppressed, T2-weighted).[19]

For this study, 1 radiologist (J.A.) scored all MRI scans from the 3 time points, blinded to previous MRI scoring and to patient information. Both the injured and uninjured side were scored. The MRI scoring was based on standardized protocols for acute and long-standing groin pain.[4,19] The following parameters were included in the assessment: tendon continuity scored as continuous, partial discontinuity (<50% or >50% disruption), or complete discontinuity. Injuries were scored as avulsions (detachment of the proximal insertion from the bone) or tendon tears (disruptions of the tendon distal from the proximal insertion). The presence or absence of an avulsion fracture (any bony avulsion) and tendon waviness were each scored dichotomously. For partial and complete tendon discontinuity, direct tendon retraction was measured in millimeters in coronal sequences from the center of the anatomic footprint of the adductor longus on the pubic bone to the center of the retracted adductor longus tendon (fibrocartilage [FC]). Tendon displacement was measured in millimeters in 3 planes: proximal-distal, medial-lateral, and anterior-posterior. Additionally, 3 plane measurements were performed in millimeters in the presence of hematoma/seroma (collection of high-intensity signal on fluid-sensitive sequences) and intramuscular edema in the adductor longus. Adductor longus muscle size was measured in axial images (medial-lateral and anterior-posterior) 5 cm distal from the pubic bone (cross-referenced from the sagittal images). The following were scored as present or absent: central, superior, and secondary cleft signs (fluid within or extending laterally/inferior from the midline of the symphysis); central disc protrusion; and heterotopic ossification (formation of extraskeletal bone in muscle and soft tissues). Grading of adductor longus muscle fatty infiltration was scored as normal to mild (some fatty streaks), moderate (fat equal to or less than muscle), or severe (fat more than muscle). On follow-up examinations, adductor longus tendon thickness (indicating fibrosis tissue) was also measured in 3 planes.

There has been a recent emphasis on the anatomic connection between the pyramidalis–anterior pubic ligament–adductor longus complex (PLAC) and its involvement in adductor longus avulsions.[13,14] Therefore, we scored the presence of a pyramidalis muscle injury, the appearance of discontinuity between the pyramidalis and the adductor longus, and anterior pubic ligament disruption. We also scored the "broken butterfly sign," which is described as a disruption of a "wing" on axial oblique images, wherein the "wings of the butterfly" consist of the 2 proximal adductor longus tendons and FC and the 2 pubic bones, with the symphysis disc as the "body of the butterfly."[14] The PLAC components are also used to classify avulsion injuries into 6 types[14]:

Type 1: complete 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

Treatment and RTS

All athletes were advised to complete a standardized criterion-based treatment program composed of active exercises with independent progression of basic exercises and progressive running and change-of-direction drills, as well as a controlled sports-training phase.[22] Exercise-based rehabilitation was the preferred approach at the hospital, and surgical reattachment was not offered. No platelet-rich plasma or other injections were offered. The patients had the opportunity to not follow the standardized protocol. In brief, the rehabilitation protocol included 9 "groin exercises," which were performed on alternate days, 3 times per week. The athletes also followed a criterion-based progression of running and sports function, including sprinting and change of direction with and without a ball, where relevant, which could be progressed daily according to the individual athlete. Additional nongroin exercises were included on alternate days if athletes attended >3 sessions per week. The choice of additional exercises was not standardized but focused primarily on the posterior kinetic chain muscle groups (hip abductors, extensors, hamstrings, and calves). Additional exercises depended on the individual athlete's needs, such as the type of sport or injury history. Further details of the treatment protocol are presented and discussed separately.[22] Compliance was calculated in a percentage as the number of sessions completed / number of advised sessions × 100. Three milestones were used to evaluate the RTS continuum: (1) completion of the clinically pain-free criteria, (2) completion of the controlled sports training, and (3) first full team training, regardless of completion of all protocol criteria. The clinical and MRI examinations related to RTS were performed after completion of the controlled sports training (RTS milestone 2), which was considered clearance to return to full team training, subsequently referred to as the RTS follow-up time point.

Subsequent Injuries

All subsequent injuries were registered through phone calls at 2, 6, and 12 months after the last treatment session using the Subsequent Injury Classification model.[25] Additionally, medical records at the hospital were checked to reduce risk of missing any subsequent injuries and to confirm injury diagnosis where possible.

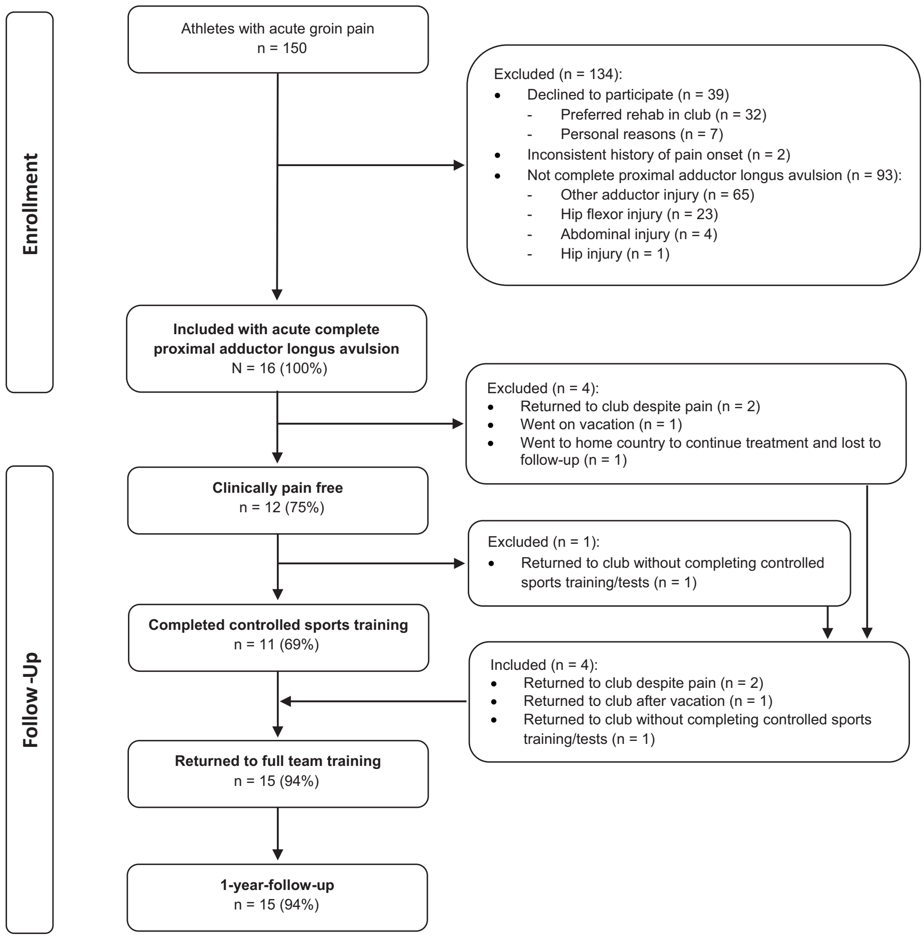

Figure 1. Flowchart of athlete inclusion and follow-up.

Statistical Methods

Descriptive statistics were used to provide overviews of clinical measures and MRI scoring, according to data distribution. Missing data were excluded. All statistical analyses were performed using SPSS software (Version 21; IBM Corp).

RESULTS

Participants

A flowchart of athlete inclusion is provided in Figure 1. Sixteen athletes were included with a complete proximal adductor longus tendon injury. Patient data are provided in Table 1. The athletes completed the sport-specific training (n = 11) in a median 69 days after injury (interquartile range [IQR], 62-84; range, 32-212). The 1-year follow-up (n = 15) was completed at a median 405 days after injury (IQR, 372-540; range, 365-687). Compliance with the exercise treatment protocol was 80% (IQR, 65%-89%; range, 33%-96%). This is equivalent to 37 supervised rehabilitation sessions (IQR, 22-45; range, 11-72). For the 11 athletes who completed the sport-specific training, compliance was

TABLE 1
Characteristics of All Athletes (N = 16)[a]

Age, y	25.6 (4.7), 18-36
Height, cm	183 [173-186], 169-202
Weight, kg	77 [69-85], 64-115
Body mass index	23.5 [22.4-25], 21-37
Sport	
Soccer	13 (81)
Volleyball	1 (6)
Basketball	1 (6)
Shot put	1 (6)
Level	
National team	3 (19)
Highest national league	11 (69)
Second tier	2 (13)
Injury situation	
Change of direction	4 (25)
Reaching	4 (25)
Tackle	4 (25)
Kicking	3 (19)
Sprinting	1 (6)

[a]Data are reported as mean (SD), range; median [IQR], range; and No. (%) of athletes.

TABLE 2
Patient-Reported Outcome Measures at Initial Examination, on the Day of Completing the Controlled Sports Training, and at 1-Year Follow-up[a]

Questionnaire	Initial Examination (N = 14)	Completed Controlled Sports Training (N = 11)	1-y Follow-up (N = 15)
HAGOS (0-100)			
Pain	44 [33-68], 23-78	100 [90-100], 78-100	100 [98-100], 90-100
Symptoms	30 [4-50], 0-54	89 [82-95], 68-100	100 [91-100], 68-100
ADL	43 [10-70], 5-80	100 [95-100], 80-100	100 [100-100], 95-100
Sport	22 [6-41], 3-50	94 [81-97], 63-100	100 [97-100], 78-100
Participation			100 [100-100], 75-100
QOL	35 [15-40], 5-70	85 [68-100], 25-100	100 [85-100], 65-100
OSTRC-O			
Participation (0-3)			0 [0-0], 0-0
Volume (0-4)			0 [0-0], 0-1
Performance (0-4)			0 [0-0], 0-1
Pain (0-3)			0 [0-0], 0-1
Severity score (0-100)			0 [0-0], 0-12.5

[a]Data presented as median [interquartile range], range. Blank cells indicate *not applicable.* Two athletes did not complete the HAGOS questionnaire at the initial examination. ADL, activities of daily living; HAGOS, Copenhagen Hip and Groin Outcome Score; OSTRC-O, Oslo Sports Trauma Research Centre Overuse Injury Questionnaire; QOL, quality of life.

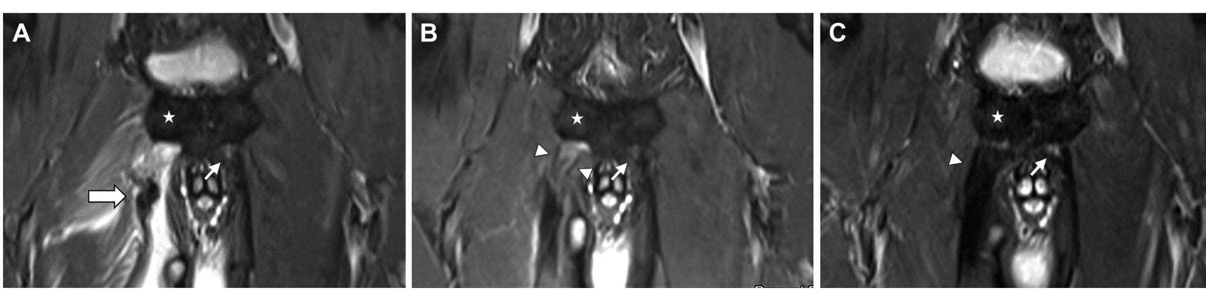

Figure 2. Coronal short tau inversion recovery magnetic resonance imaging scans of a 32-year-old male soccer player with a right adductor longus tendon avulsion: (A) 2 days after injury—complete tendon discontinuity with 2-cm retraction (thick arrow); (B) 67 days after injury, at return-to-sport clearance—the emergence of a neotendon between the retracted adductor longus (arrowheads) and the pubic bone (star); (C) 405 days after injury, at 1-year follow-up—almost full tendon continuity (arrowhead) with clear fibrotic tissue formation as compared with the uninjured side. Note the higher signal intensity at the insertion of the adductor longus on the asymptomatic uninjured side (thin arrow) appearing unchanged throughout.

83% (IQR, 75%-89%; range, 48%-96%), and they attended 41 supervised sessions (IQR, 33-47; range, 22-72).

Clinical Measures and MRI Scoring

Overviews of all patient-reported outcome measures and clinical examination measures for the 3 time points are provided in Tables 2 and 3, respectively. MRI scoring results are provided in Table 4 and Appendix Table A1 (available in the online version of this article). Examples of imaging progression are shown in Figures 2 to 4.

Subsequent Injuries

Within the year after RTS, 1 player (7%) had a reinjury; 1 (7%) had intermittent adductor-related groin pain considered related to the previous injury; 1 (7%) had an acute contralateral groin injury; and 4 (27%) had injuries to different body parts not related to their previous injuries (2 hamstring injuries and 2 knee injuries). Further details are specified in Appendix 2 (available online).

DISCUSSION

We performed detailed clinical and MRI examinations at baseline, RTS, and 1 year after an acute complete adductor longus tendon avulsion in a case series of male athletes (mostly soccer) who received nonsurgical treatment with a standardized exercise-based rehabilitation protocol. The athletes returned to their sports approximately 2 to 3 months after injury. At 1-year follow-up, they had a high self-reported function, no performance limitations, and normal strength and range of motion. In all cases, there was a partial or full reattachment of the adductor longus tendon to the pubic bone as shown on MRI scans.

TABLE 3
Clinical Pain Provocation Tests and Measures of Strength and ROM at Initial Examination, on the Day of Completion of the Controlled Sports Training, and at 1-Year Follow-up[a]

Clinical Measure	Initial Examination[b] (N = 16)	Completed Controlled Sports Training (N = 11)	1-y Follow-up (N = 15)
Adductor pain			
Palpation	16 (100)	1 (9)	1 (7)
Resistance	16 (100)	2 (18)	1 (7)
Stretch	16 (100)	0 (0)	0 (0)
Bent-knee fall-out test			
Symmetry, %	36 [29-51], 10-89	100 [91-109], 77-120	100 [97-130], 81-127
Injured leg, cm	32 [29-34], 18-40	13 [11-15], 4-19	16 [10-16], 4-22
Uninjured leg, cm	12 [10-14], 4-16	15 [11-16], 4-18	16 [10-16], 4-21
Hip ABD ROM			
Symmetry, %	57 (24), 8-92	99 [95-100], 93-117	102 [99-105], 92-118
Injured leg, deg	27 (10), 4-41	48 [45-50], 39-67	49 [43-52], 39-73
Uninjured leg, deg	49 (8), 37-65	47 [45-50], 39-68	48 [44-52], 36-75
ECC ADD strength test ability	2 (13)	11 (100)	15 (100)
ECC ADD strength side-lying			
Symmetry, %	23-34	94 [82-98], 56-110	92 (13), 68-119
Injured leg, N·m/kg	0.6-0.9	2.9 [2.4-3.2], 2.0-4.1	2.8 (0.6), 2.0-4.1
Uninjured leg, N·m/kg	2.5-2.8	3.4 [2.7-3.5], 2.0-4.3	3.1 (0.6), 2.2-4.5
ECC ABD strength side-lying			
Symmetry, %	85-88	100 [94-111], 83-122	101 (9), 80-116
Injured leg, N·m/kg	2.4-3.0	3.1 [2.7-3.2], 2.2-3.8	2.9 (0.6), 2.0-3.7
Uninjured leg, N·m/kg	2.9-3.4	2.7 [2.7-3.2], 2.5-3.9	2.9 (0.5), 2.2-3.9
ADD/ABD ratio			
Injured leg	0.2-0.4	0.95 (0.16), 0.69-1.25	0.99 (0.16), 0.74-1.21
Uninjured leg	0.7-1.0	1.10 (0.17), 0.77-1.41	1.08 (0.16), 0.81-1.40
ECC ADD strength supine	NA		
Symmetry, %		79 [71-88], 47-105	93 [89-105], 59-112
Injured leg, N·m/kg		2.0 [1.8-2.6], 1.6-3.1	3.1 [2.7-3.4], 1.2-3.8
Uninjured leg, N·m/kg		2.8 [2.6-3.1], 2.0-3.8	3.3 [2.8-3.5], 1.9-4.5

[a]Data are presented as number of positive findings (percentage of obtained measures); mean (SD), range; or median [interquartile range], range.

[b]Missing data: Because of pain in the initial examination, 4 athletes did not perform the hip abduction range of motion, and 3 did not perform the bent-knee fall-out test. Eccentric side-lying strength measures are reported for only 2 athletes who were able to perform the eccentric adduction test. ABD, abduction; ADD, adduction; ECC, eccentric; NA, not applicable (this test was not part of the initial examination); ROM, range of motion.

Patient-Reported Outcome Measures

Potential sequelae after an adductor longus tendon avulsion is a main concern when choosing the best treatment approach. Our results of exclusively nonsurgically treated athletes show that the athletes had excellent self-reported function at the 1-year follow-up. The reported HAGOS scores are higher than the reference values of asymptomatic soccer players with hip and/or groin pain in the previous season and similar to asymptomatic players without hip or groin pain in the previous season.[9,25] High patient-reported function after nonsurgically treated adductor longus tendon avulsions was also noted in a recent retrospective case series of 7 athletes at a mean ± SD follow-up time of 15.1 ± 6 months after injury.[1] These athletes all had a maximum score on the modified Harris Hip Score and Hip Outcome Score, and maximum or close-to-maximum results on 2 Hip Outcome Score subscales (activities of daily living and sports).[1]

There were 2 subsequent groin injuries in our case series, which were considered related to the adductor longus tendon avulsion. One injury caused time loss (reinjury), whereas the other one did not affect participation (intermittent adductor-related pain). Both these injuries were related to high-intensity kicking. It is well known that kicking places high stress on the adductor longus muscle[5] and that kicking is one of the key injury situations for acute adductor longus injuries.[18] Therefore, athletes returning to kicking sports may benefit from an increased focus on kicking progression in the rehabilitation phase to minimize risk of subsequent groin pain. There did not appear to be any other relevant subsequent injury pattern as a result of the adductor longus avulsion tendon injuries.

Clinical Measures

Range of motion in the bent-knee fall-out test and side-lying abduction tests was generally symmetric at the 1-year follow-up, at a median 100% and 102%, respectively. We previously reported that despite a large initial

TABLE 4
Standardized MRI Scoring Results[a]

Side	Initial MRI (n = 16)		Completed Controlled Sports Training (n = 10)		1-y Follow-up MRI (n = 14)	
	Injured side	Uninjured side	Injured side	Uninjured side	Injured side	Uninjured side
Acute injury	16 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tendon discontinuity						
Continuous, 0%	0	11 (69)	0	6 (60)	4 (29)	10 (71)
Partial discontinuity, <50%	0	3 (19)	0	3 (30)	7 (50)	4 (29)
Partial discontinuity, 50%-99%	0	2 (13)	6 (60)	1 (10)	3 (21)	0
Complete discontinuity, 100%	16 (100)	0	4 (40)	0	0	0
Direct tendon retraction, mm	20 [8.5-26], 4-36	0	8.5 [7-12], 2-34	0	2 [0-3], 0-4	0
Tendon displacement, mm						
Proximal-distal	19.5 [8-22], 4-36		8 [6-11], 0-34		2 [0-2], 0-4	
Medial-lateral	7 [4-12], 0-17		7.5 [0-10], 0-12		0 [0-0], 0-4	
Anterior-posterior	2 [0-6.5], 0-14		4.5 [0-7], 0-10		0 [0-0], 0-7	
Anterior pubic ligament disruption	3 (19)	0	1 (10)	0	0	0
AL and pyramidalis discontinuity	11 (69)	0	4 (40)	0	0	0
Broken butterfly sign	16 (100)	1 (6)	10 (100)	1 (10)	5 (36)	1 (7)
Avulsion types[14]						
1	4 (25)	0	3 (30)	0	0	0
2	9 (56)	0	3 (30)	0	0	0
3	0	0	0	0	0	0
4	0	0	1 (10)	0	0	0
5	3 (19)	0	1 (10)	0	0	0
6	0	5 (31)	2 (20)	4 (40)	11 (79)	4 (29)
No type	0	11 (69)	0	6 (60)	3 (21)	10 (71)
Muscle size AL, mm						
Medial-lateral	54 [45.5-56.5], 40-61	52.5 [47-54], 36-57	48.5 [45-52], 40-54	50 [47-54], 26-61	52.5 [47-54], 39-61	52 [51-55], 25-68
Anterior-posterior	30 [27.5-33.5], 23-40	28.5 [25.5-33.5], 15-40	27 [24-30], 21-54	29 [25-33], 11-55	26.5 [24-30], 18-55	30.5 [26-36], 11-61

[a]Values are presented as No. (%) or median [interquartile range], range. Blank cells indicate *not applicable*. For additional variables, see Appendix Table A1 (available online). AL, adductor longus; MRI, magnetic resonance imaging.

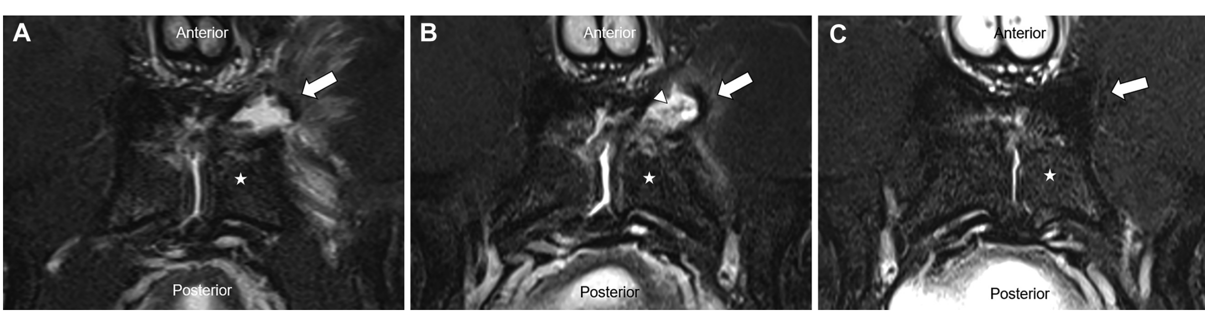

Figure 3. Axial oblique fat-suppressed T2-weighted magnetic resonance imaging (MRI) scans of a 24-year-old male soccer player with a left adductor longus tendon avulsion injury. (A) MRI scan 1 day after injury shows a disruption between the left proximal adductor longus tendon (thick arrow) and the fibrocartilage of the pubic bone (star), also described as the ''broken butterfly sign.''[14] (B) MRI scan 33 days after injury (at return-to-sport clearance) still shows clear disruption between the adductor longus and the pubic bone. The hypointense signal (arrowhead) between the pubic bone and adductor longus tendon suggests emerging fibrosis. (C) MRI scan 586 days after injury (1-year follow-up) shows a normal appearance of the attachment between the adductor longus and pubic bone.

reduction in range of motion of the injured leg, these measures normalized relatively early after injury in athletes with acute adductor injuries.[16] The absolute values at 1-year follow-up were similar to the reference values from healthy elite soccer players from the same country (bent-knee fall-out test, 8.6-17.4 cm; abduction range of motion, 42°-57°).[11] Range of motion has previously received little attention in this patient group. Although a few studies have examined full recovery/symmetry of adductor range of motion, none of these appeared to use objective assessments.[6,23,28] Our results indicate that limited or excessive range of motion does not appear to be a concern in this patient group.

Side-lying eccentric abduction strength was generally symmetric (median, 101%) at 1-year follow-up, whereas side-lying and supine eccentric adduction was lower in

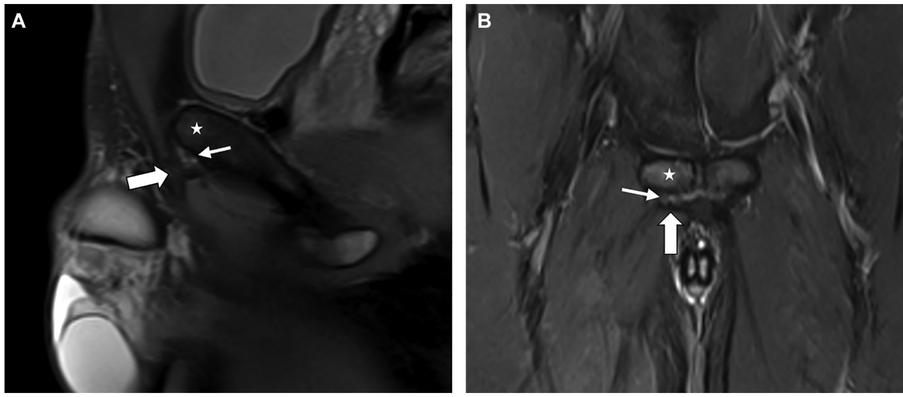

Figure 4. Magnetic resonance imaging scans of a 28-year-old male soccer player 484 days injury (1-year follow-up) after an acute right complete adductor longus avulsion. (A) Sagittal short tau inversion recovery and (B) coronal fat-suppressed T2-weighted sequences show a small line of hyperintensity (thin arrow) indicating partial reattachment (type 6) of the adductor longus tendon (thick arrow) to the pubic bone (star).

the injured leg (median symmetry, 92% and 93%, respectively). A potential long-term reduction in adductor strength is a consideration in the treatment decision-making process. Unfortunately, objective strength measures are rarely used. Instead, most case series and case studies report full recovery and symmetric adduction strength using manual muscle testing with subjective tester grading only.[2,6,15,27,28] Our study is the first case series reporting objective adductor strength data at the initial examination, at RTS, and at a longer follow-up. The results indicate that minor adductor strength asymmetry persists from RTS to the 1-year follow-up in both eccentric adduction strength tests. In the side-lying test (inner range), adductor strength values remained similar from RTS to 1-year follow-up, whereas adductor strength in the supine test (outer range) increased considerably.

Despite the relatively minor asymmetry, the absolute strength values of the injured leg in the side-lying position at 1 year were close to those of healthy soccer players (2.8 ± 0.6 vs 3.0 ± 0.6 N·m/kg, respectively).[11] There are currently no reference values for the supine strength test for comparisons. Interestingly, MRI examination did not reveal a considerable difference in adductor longus muscle size between sides, indicating no major permanent atrophy as a result of injury and rehabilitation. Although continuous adduction strength exercises were recommended after RTS, we did not have control over or monitor the implementation of adductor strength training after RTS.

Magnetic Resonance Imaging

All injuries were unilateral avulsions between the tendon and the bone. There were no avulsion fractures and no complete muscle-tendon tears. Our main interest on examination of imaging was the assessment of tendon continuity at the different time points. The MRI results show that from the original complete discontinuity in all cases, at 1-year follow-up all tendons had at least partial continuity, with 4 athletes (29%) having complete continuity of the tendon. This appears to be a result of a neotendon development that extends over a larger area than the original retraction, which we consider a sign of reattachment of the muscle-tendon unit to the pubic bone. The cases with partial continuity at 1-year follow-up had minimal retraction (2 mm; IQR, 0-3 mm) between the pubic bone and the part of the tendon that was not considered reattached, and there was minimal displacement of the tendon. MRI examples in Figure 4 show a frequent appearance of partial reattachment at the 1-year follow-up. The line of hyperintensity at the adductor longus insertion seen here is similar to what is often cited as adductor longus enthesopathy/tendinopathy.[29] However, this finding has been shown not to be related to the presence of groin pain,[3] consistent with the follow-up results in this study. Complete tendon reattachment 1 year after nonsurgical management has been reported.[15] Additionally, a case series of 6 athletes noted functionally sufficient reattachment of the avulsed tendon, where the defect was filled with fibrotic tissue (neotendon) at 12 weeks after injury.[27] Our findings suggest that although a continuous healing process takes place from injury to RTS and 1-year follow-up, healing is likely ongoing, and the tissue capacity of the insertion may still not be optimal 1 year after injury in most cases.

Studies on the treatment of adductor longus tendon avulsions have used the extent of retraction as an indication for surgery, with retraction >1 cm or >2 cm as a cutoff.[1,2] The median retraction in our study was 2 cm, ranging up to 3.6 cm. Additionally, successful RTS after nonsurgical treatment was reported in a cases series of 6 athletes with a mean retraction of 2.1 cm (range, 1.5-2.8 cm) and in a case series of 14 athletes, 8 of whom had 1- to 3-cm retraction and 4 of whom had >3-cm retraction.[15] This suggests that a retraction length cutoff measure should not be used as a surgical indication.

Integrity of the PLAC has been suggested as an important consideration in the treatment decision process.[13] In our study, more than half (56%) of the athletes had anterior pubic ligament disruption, and half had discontinuity between the pyramidalis and the adductor longus tendon on initial imaging. At RTS, most of these findings showed full normalization on MRI scans, and at 1-year follow-up all had returned to normal appearance. Similarly, there was a variation of avulsion types in the initial MRI examination, which then changed over time, and all ended in type 6 (partial FC avulsion, pyramidalis connected to adductor longus, intact pectineus) or normalized sufficiently to not fit into any type. These findings indicate that at least some athletes with different types of PLAC injuries can RTS using an exercise-based treatment, although the integrity of the PLAC may result in a different injury appearance initially. This might limit the relevance of specific PLAC findings and types in the clinical decision-making process.

Additional muscle injuries mainly occurred in the pectineus, adductor brevis, and obturator externus. Most of these injuries had normalized as shown on imaging at RTS and none were seen at the 1-year follow-up. Secondary changes, such as central, superior, or secondary cleft signs, did not appear to change over time in this case series. Heterotopic ossification at the adductor longus insertion was seen at the 1-year follow-up in 1 athlete in our study, and it appears to be a relatively rare finding in general.[12,15] Despite the presence of heterotopic ossicitation, the athlete had high self-reported function and no performance limitations at the 1-year follow-up.

Strengths and Limitations

Our study presents the most detailed follow-up to date on a case series of athletes with acute adductor longus tendon avulsions. It is a prospective study using standardized clinical and MRI examinations. While these are great strengths, the generalizability of our results is still limited by the relatively small sample size, which included 5 missing examinations at RTS and 1 missing at 1-year follow-up. Additionally, our athletes were all male, and the majority were high-level soccer players. As adductor longus avulsions are relatively rare, it would be beneficial to have multicenter studies to investigate whether findings are different in female participants or in athletes from other levels and types of sports. We used 2 standardized questionnaires, HAGOS and OSTRC-O, which both ask questions related only to the previous week. There is therefore a risk that the specific week of questionnaire completion may have been better or worse than other weeks in the period being examined. The 1-year follow-up did not occur exactly 365 days after injury for all athletes. The median was 405 days, but some athletes had their follow-up later (all <2 years after injury). It is possible that this may have influenced the findings. An even longer follow-up would be beneficial to elucidate whether findings remain similar.

CONCLUSION

Nonsurgically treated athletes with a complete acute adductor longus tendon avulsion returned to sport in 2 to 3 months. One player (7%) had a reinjury. One year after injury, athletes had high self-reported function, no performance limitations, normal adductor strength and range of motion, and partial or full tendon continuity as shown on MRI scans. This indicates that the primary treatment for athletes with acute adductor longus avulsions should be nonsurgical as the time to RTS is short, there are good long-term results, and there is no risk of surgical complications.

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