Video analysis of Achilles tendon rupture in male professional football (soccer) players: injury mechanisms, patterns and biomechanics

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ABSTRACT

Background Achilles tendon rupture (ATR), while rare in football, is a severe career-threatening injury associated with long-layoff times. To date, no study has documented ATR's mechanism in professional football players.
Aim To describe the mechanisms, situational patterns and gross biomechanics (kinematics) of ATR injuries in professional male football players.
Methods Eighty-six (n=86) consecutive ATR injuries in professional football players during official matches were identified. Sixty (70%) injury videos were identified for mechanism and situational pattern, with biomechanical analysis feasible in 42 cases. Three independent reviewers evaluated the injury videos. Distribution of ATR during the season, the match play and on the field were also reported.
Results Fifty (n=50, 83%) injuries were classified as non-contact and 10 (17%) as indirect contact. ATRs are injuries occurring during accelerations; three main situational patterns were identified: (1) forward acceleration from standing (n=25, 42%); (2) cross-over cutting (n=15, 25%) and (3) vertical jumping (n=11, 18%). Biomechanically, ATR injuries were consistent with a multiplanar loading at the injury frame consisting of a slightly flexed trunk (15.5°), extended hip (−19.5°), early flexed knee (22.5°) and end-range dorsiflexed (40°) ankle in the sagittal plane and foot pronation; 27 (45%) ATRs occurred in the first 30 min of effective match time.
Conclusions All ATRs in professional football were either non-contact (83%) or indirect contact (17%) injuries. The most common situational patterns were forward acceleration from standing, cross-over cutting and vertical jumping. Biomechanics was consistent and probably triggered by a multiplanar, although predominantly sagittal, loading of the injured Achilles tendon.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Achilles tendon rupture (ATR) is a severe career-threatening injury with long-layoff times.
⇒ To date, no study has documented ATR's mechanism in professional football players.

WHAT THIS STUDY ADDS

⇒ ATRs happen with a pure non-contact mechanism in 83% of professional football players.
⇒ ATRs are mainly acceleration injuries in football, and three main patterns have been described: (1) acceleration from standing, (2) cross-over cutting and (3) vertical jumping.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Targeting the most frequent mechanism, patterns and biomechanics may help design primary reduction measures and late-stage rehabilitation after ATR.

INTRODUCTION

Achilles tendon rupture (ATR) is a concerning, although rare, injury for the football (soccer) player that often requires surgical management and long lay-off time.[1]

Achilles tendon (AT) disorders have been studied in top-level football players. The incidence of Achilles tendinopathy is 0.18 injuries/1000 hours of exposure, whereas ATR is lower, set at 0.01 injuries/1000 hours of general exposure[2] and 0.05 per 1000 hours of gameplay during matches.[3] However, the incidence of ATR is rising over time, with a 5.4% annual increase reported for sport-related ATRs in northern Europe.[4] A recent study examined 118 professional football players with ATR, finding an 82% successful return to play rate and 11% retear at minimum 2 years follow-up.[1]

A critical step in injury prevention is establishing the causes of injury,[5] including understanding what may predispose players to injury (eg, risk factors) and how injuries take place.[5] There is currently a lack of understanding of how ATR injuries occur, particularly compared with other injuries such as anterior cruciate ligament (ACL) injury.

While assessing how injuries happen, it is important to understand the mechanisms (contact vs non-contact), playing situations

(situational patterns) and biomechanics that leads to injury.[5 6] Video analysis is a frequently used tool to investigate injury mechanisms, playing situations and gross biomechanics preceding and during actual injuries.[7] This methodological framework has been extensively used to study ACL injuries across various sports[6–9] as well as other conditions within and outside football.[10 11] To date, the authors are aware of only one study using video analysis to analyse ATR injuries, performed on a small sample of National Basketball Association (NBA) players (n=12).[12] No study has been published to date on football (soccer).

Thus, the primary purpose of this study is to describe through video analysis the mechanisms, situational patterns and biomechanics (kinematics) of ATR injuries in professional male football players. A secondary purpose of this study was to report ATR's seasonal match and pitch distribution.

METHODS
Injury identification and videos extraction
This is a secondary video analysis study of a previously published database regarding return to play following ATR in professional football players in first-division and second-division European leagues.[1] Regarding injury identification, the methods are described in detail in a recent paper from Grassi *et al*.[1] In short, we applied systematic web-based research for professional football players of the first two national-level divisions that sustained an ATR and subsequent surgical repair between August 2008 and August 2018. Data were retrieved from *transfermarkt.de* (Transfermarkt GmbH, Hamburg, Germany), a frequently used resource for identifying professional football injuries.[6 13–15] The accuracy of the injury-related data retrieved from *transfermarkt.de* was recently reported with an interobserver agreement of over 90% between gold-standard sources and *transfermarkt.de* and a Cohen's kappa of 0.82 for cross-validation.[14] This source is considered valid for severe injuries[16] and is, thus, highly appropriate for ATR.

Match videos were obtained from an online digital platform (wyscout.com, Wyscout spa, Genova, Italy) (n=60), processed on a digital cloud (paninidigitalcloud.com) and then downloaded to a personal computer. Match video processing was performed with a web-based application (Digital Log, Digital Soccer Project, Modena, Italy). Each video was cut to approximately 15 s before 5 s post the estimated injury frame (IF) to evaluate the playing phase that preceded the injury and the injury mechanism. The IF was estimated as the first frame where the typical gastrocnemius recoil was visible.

Video evaluation
The same methodology of our previous video analysis studies was implemented[6 10 17]: video clips were independently evaluated by three different reviewers (FDV, AG, MB) according to a predetermined checklist (online supplemental table 1). All the reviewers are involved in sports medicine and orthopaedic rehabilitation practice

and have experience with video analysis research. Each processed video was further analysed within Kinovea (V. 0.9.5, KinoveaInk, Bordeaux, France).

Each reviewer scrutinised the video to establish the injurious, offensive or defensive situation, which was categorised based on ball possession and playing situation. Then, a series of non-parallel views were used to determine the injury mechanism and playing action (eg, running, jumping, landing, decelerating, cutting, etc). Injury mechanisms describe the ATR injury causation, referring to player-to-player interaction that led to the injury. Three categories were identified: (1) direct contact, (2) indirect contact and (3) non-contact.

Subsequently, the reviewers met for a 1-day comprehensive discussion about the main injury mechanism and situational patterns. Without complete agreement between reviewers, problems were solved with a collegiate decision.[6] Consensus agreement on all the items, including initial contact (IC) and IF estimation, was achieved during the meeting.

Biomechanical analysis (kinematics)
Kinematic analysis was also conducted for previous research by our group on ACL[6 17] and medial collateral ligament (MCL)[10] injuries when a sufficient quality sagittal view was available. The analysis was performed to estimate intersegmental relationship and joint angles at IC and estimated IF. When more than one camera view was available, composite videos were created by manual synchronisation using relevant visual clues (eg, initial ground contact).

Sagittal plane angles were estimated using custom-made software (GPEM Screen Editor, GPEM srl, Genova, Italy) to the nearest 5°.[6] The frontal and transverse plane estimated joint positions were described through a range of segment pose categories. Foot strike appearance was evaluated after the first foot contact with the ground.[6]

Seasonal, match and field distribution
For each injury video, data regarding the seasonal, match and field distribution were gathered through a web review and the analysis of videos relative to the injured player's position, according to our previously published research.[6 10 17] We considered (a) month of injury, (b) phase of the match when the injury occurred (minute and a half), (c) number of minutes played by the injured player and (d) field location at the time of injury. The location of the injury on the pitch was estimated by taking the field lines as a reference.[6] The pitch was divided into 11 different zones.[6] The square-metre field zone dimensions were calculated considering the official Fédération Internationale de Football Association (FIFA) football field size (105×70 m^2) (see online supplemental material).
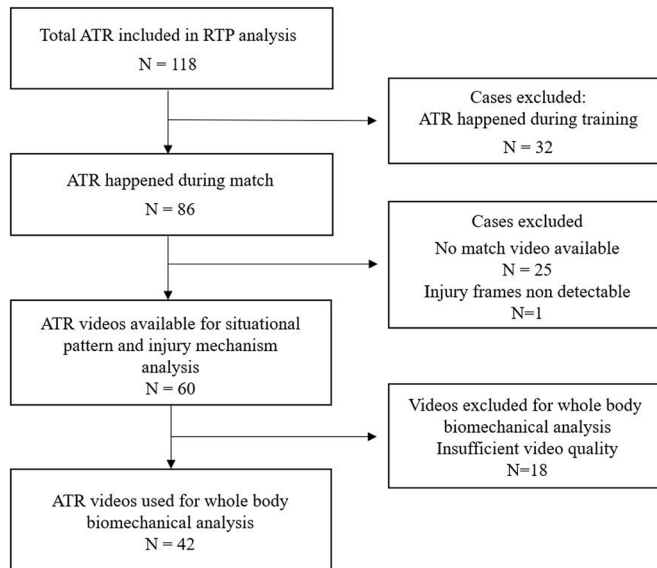
Figure 1 Detailed study flow. ATR, Achilles tendon rupture; RTP, return to play.

Patient and public involvement

The study results will be shared with publicly available resources (eg, newspapers) to sensitise the audience to ATR mechanisms.

Equity, diversity, inclusion (EDI)

Millions of women worldwide play football, and BMJ Open Sports & Exercise Medicine encourages research that includes sex and gender-based analysis. The methodology that we used was, at present, not applicable to women's football. Alternative approaches should be used to fill this gap, and football medicine is going in that direction.

Statistical analysis

Where appropriate, we calculated the mean (±SD) or median (range or IQR) for continuous variables. Discrete variables were presented as absolute numbers and percentages (frequency) on the number of total observations. A statistical threshold of alpha <0.05 was implemented throughout. Microsoft Excel (V. 16.6, Microsoft, Redmond) and Stata 12 (Statacorp, Texas) were used for these analyses.

RESULTS

A set of 118 ATR injuries were identified, with 86 injuries occurring during official matches. Of these 86 injuries, videos were identifiable in 60 cases (70%) and included for data analysis. Three videos had four camera views, 13 three, 24 two and 20 had a single camera view. The mean age of the injured players was 26.1±4.1 years. There were 23 (38%) injuries on the right and 37 (62%) on the left AT. Of these injuries, 28 occurred on the kicking (preferred) leg (47%) and 32 (53%) on the non-kicking leg. The detailed study flow is presented in figure 1.

Injury mechanism analysis

All injuries involved loading of the injured leg, with single limb loading for nearly all injuries (55 cases, 92%). We categorised 50 (83%) non-contact and 10 (17%) indirect

Table 1 Details of injury mechanism of Achilles tendon ruptures in football players (n=60)

Variables	Results
Weather conditions	
Raining	Yes (n=3), no (n=57)
Sunny	Yes (n=18), no (n=19), night (n=23)
Playing phase before the injury	Defensive (n=26), offensive (n=34)
Field location at the time of injury	
Long axis of the field	Defensive third (n=17), midfield third (n=25), offensive third (n=18)
Short axis of the field	Left side corridor (n=6), middle corridor (n=47), right side corridor (n=7)
Player contact preceding injury	Yes (n=10), no (n=50)
If contact, where?	Upper body (n=9), lower limb (n=1)
Player contact at IF	Yes (n=5), no (n=55)
If indirect contact at IF, where?	Upper body (n=5)
Injury classification	Indirect contact (n=10), non-contact (n=50)
How many feet were on the ground	One (n=55), two (n=5)
Leg loading at IF	Injured leg (n=60)
Horizontal speed	Zero (n=28), low (n=12), moderate (n=3), high (n=17)
Vertical speed	Zero (n=40), low (n=7), moderate (n=9), high (n=4)
Distance from the ball (metres)	0–2 (n=23), 2.5–5 (n=17), 5.5–10 (n=7), >10 (n=11)
IF, injury frame.	

Figure 2 Acceleration from standing. (A) Player in ball possession in offensive situation. (B) Initial contact to the ground with the left foot. (C) Injury frame for left Achilles tendon rupture with the typical relative extension to the hip and knee level and abrupt increase in ankle dorsiflexion. (D) Loss of balance after the injury (publicly available footage retrieved from Wyscout portal).

Figure 3 Cross-over cutting. (A) Player in ball possession running at high-speed. (B) Initial contact with planed left foot during a cross-over cut. (C) Injury frame for left Achilles tendon rupture. (D) Loss of balance with typical protective knee flexion response after the injury (publicly available footage retrieved from Wyscout portal).

contact injuries (see table 1 for injury mechanism analysis). ATR was estimated after 80±27 ms after IC to the ground.
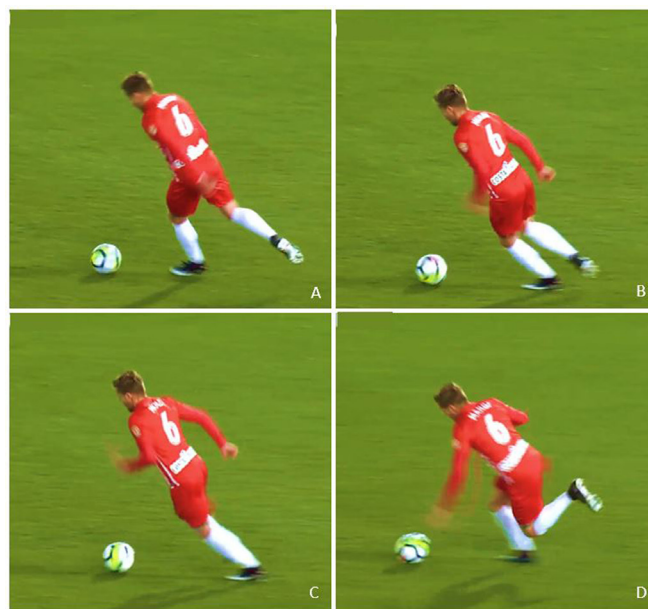
Achilles tendon rupture patterns

Eighty-five per cent of ATRs occurred according to three main patterns: (1) *acceleration from standing* was the most common mechanism accounting for more than two out of five injuries (figure 2), (2) *cross-over cutting*, the second most common pattern, accounting for one out of four injuries, was characterised by a high horizontal speed and a rapid change of direction with the injured limb moving medially with respect to the pelvis (figure 3) and (3) *vertical jumping*, accounting for nearly one out of five injuries (figure 4). The other nine injuries (n=9, 15%) did not fit these categories (15%). See table 2 for more details.

Biomechanical (kinematic) analysis

Whole body biomechanical analysis was possible in 42 cases. At IC, on the sagittal plane, players displayed a slightly flexed trunk (median, 15°), shallow flexed hip (median, 10°), moderately flexed knee (median, 44°) and neutral ankle (median, 0° flexion), typically with forefoot impact (62% of cases).

At the estimated IF, on the sagittal plane, the trunk remained in the same position (median, 15° flexion), while the hip (median, −20° flexion, −30° from IC) and knee (23°, −22° from IC) both extended in relation to IC. The ankle transitioned into end-range dorsiflexion

(40°). The foot was now typically flat (62%) and pronated (48%). Additional details are in table 3. The most frequent intersegmental positioning at IF is reported in figure 5.

Figure 4 Vertical jumping. (A) Player in white jersey approaching to jump during a duel. (B) Initial contact with right foot with toe strike. (C) Injury frame to right Achilles tendon while jumping. (D) Loss of propulsion with virtually no elevation after injury (publicly available footage retrieved from Wyscout portal).

Table 2 Indirect contact and non-contact injuries' patterns of Achilles tendon ruptures (n=60)

Pattern	Playing phase	Injury mechanism	Horizontal velocity	Vertical velocity
Forward acceleration from standing (n=25, 42%)	16 (64%) Offensive	25 (100%) Non-contact	20 (80%) Zero	20 (80%) Zero
	9 (36%) Defensive		5 (20%) Low	3 (12%) Low
			0 (0%) Moderate	2 (8%) Moderate
			0 (0%) High	0 (0%) High
Cross-over cutting (n=15, 25%)	11 (73%) Offensive	14 (93%) Non-contact	0 (0%) Zero	15 (100%) 0
	4 (27%) Defensive	1 (7%) Indirect contact	0 (0%) Low	0 (0%) Low
			0 (0%) Moderate	0 (0%) Moderate
			15 (100%) High	0 (0%) High
Vertical jumping (n=11, 18%)	3 (27%) Offensive	6 (55%) Non-contact	5 (45%) Zero	0 (0%) Zero
	8 (73%) Defensive	5 (45%) Indirect contact	6 (55%) Low	4 (36%) Low
			0 (0%) Moderate	6 (55%) Moderate
			0 (0%) High	1 (9%) High
Others (n=9, 15%)	3 (33%) Offensive	6 (66%) Non-contact	3 (33%) Zero	5 (55%) Zero
Landing (n=4)	6 (66%) Defensive	3 (33%) Indirect contact	1 (11%) Low	0 (0%) Low
Sidestep (n=4)			2 (22%) Moderate	1 (11%) Moderate
Stretching (n=1)			3 (33%) High	3 (33%) High

Seasonal, positional, match and field distribution

Seasonal distribution (n=59) showed 30 injuries in the first 5 months of the season (August–December) and 29 injuries in the last 5 months (January–May). Two injuries occurred to goalkeepers, 26 to defenders, 15 to midfielders and 17 to forwards. Thirty-three (55%) injuries occurred in the first half and 27 (45%) in the second half (figure 6A). Regarding effective match time, 45% of injuries occurred in the first 30 min (figure 6B). Injuries according to pitch location are detailed in table 1 and online supplemental material. Injuries were more frequent in the middle (n=47) than in the lateral (n=13) corridors.

DISCUSSION

ATRs in football are non-contact (83%) or indirect (17%) contact injuries. They occur largely (85%) with three main patterns: (1) acceleration from standing, (2) cross-over cut and (3) vertical jumping. ATR predominantly involves altered multiplanar kinematics, with an extension pattern at the knee and hip and the ankle close to end-range dorsiflexion, combined with foot pronation and external rotation.

How do ATR injuries happen in football?

This is the first study to systematically assess ATR injuries of football players using video analysis.

Confirming a previous video analysis in Basketball (NBA),[12] ATR injuries are essentially non-contact (or indirect contact) injuries. Previous research reported only non-contact and direct contact mechanisms, without differentiating which of them were indirect contact. In football, ATRs are typically purely non-contact injuries happening during acceleration actions. Interestingly, 10

out of the 60 injuries in our cohort were preceded by indirect contact to the upper body. Upper body perturbation was associated with ACL[6 17] injuries and likely resulted in a loss of neuromuscular control, leading to altered kinematics and increased demand for the AT. However, these injuries are a small fraction of ATR in football.

ATRs happened in defensive and offensive playing scenarios, with a slightly higher prevalence of injuries during attacking actions in possession. This is in contrast to ACL injuries, which are more frequently reactive and defensive in nature.[6 17 18] Of particular interest is the 62% of left ATR, with a slightly higher prevalence of injuries that occurred to the non-kicking leg, another difference from ACL injuries[6] and football injuries in general,[19] that are generally more frequent in the kicking (dominant) lower limb. These differences can be explained as ATRs are acceleration injuries to a posterior kinetic chain structure. In contrast, ACL injuries are typically deceleration injuries loading the central structure of the knee joint. Another possible reason may be that football players prefer to accelerate with the non-kicking leg, putting this lower limb at higher risk of injuries at the calf complex level. However, this is yet to be proven. Two-thirds of ATR happens with the ball at less than 5 m from the injured players, indicating ball possession or duel-type interactions. This may also be due to the common patterns observed, as accelerations from standstill happen with ball possession in 64% of cases.

Besides the three main patterns observed, few injuries occurred during landing or deceleration-only tasks.

ATR patterns

This is the first study documenting the patterns (and playing actions) of ATRs in football. A previous study

Table 3 Biomechanical description (median and range) of Achilles tendon ruptures in football players (n=42)

| Whole body biomechanics on the sagittal plane (n=42)		Injury pattern			
Variables	Total	Acceleration from standing	Cross-over cutting	Vertical jumping	Others
Trunk flexion IC (+ flexion, − extension)	15 (−5, 75)	13 (0, 75)	8 (0, 30)	18 (−5, 31)	19 (6, 30)
Trunk flexion IF (+ flexion, − extension)	16 (−5, 90)	19 (−0, 90)	14 (−5, 44)	14 (2, 30)	20 (5, 30)
Hip flexion IC (+ flexion, - extension)	10 (−37, 65)	8 (−33, 65)	5 (−24, 38)	20 (−37, 43)	25 (−3, 34)
Hip flexion IF (+ flexion, − extension)	−20 (−55, 60)	−17 (−50, 60)	−27 (−55, 59)	3 (−50, 40)	0 (−32, 49)
Knee flexion IC (+ flexion, − extension)	44 (10, 70)	40 (12, 70)	35 (10; 59)	50 (10, 60)	50 (30, 65)
Knee flexion IF (+ flexion, − extension)	23 (0, 80)	20 (7, 58)	15 (0, 80)	38 (13, 68)	45 (10, 74)
Ankle flexion IC (+ dorsi-flexion, − plantar-flexion)	0 (−35, 35)	−10 (−35, 35)	4 (−34, 35)	10 (0, 22)	0 (−30, 15)
Ankle flexion IF (+ dorsi-flexion, − plantar-flexion)	40 (15 59)	39 (15, 59)	39 (15, 52)	42 (20, 54)	44 (30, 51)
Foot biomechanics (n=60)					
Foot strike IC (sagittal plane)					
Forefoot	37 (62%)	25 (100%)	4 (27%)	7 (64%)	3 (33%)
Flat foot	12 (20%)	/	8 (53%)	/	2 (22%)
Heel strike	/	/	/	/	/
Unsure	11 (18%)	/	3 (20%)	4 (36%)	4 (44%)
Foot strike IF (sagittal plane)					
Forefoot	10 (17%)	8 (32%)	2 (13%)	/	/
Flat foot	37 (62%)	17 (68%)	10 (67%)	5 (45%)	5 (56%)
Heel	/	/	/	/	/
Unsure	13 (22%)	/	3 (20%)	6 (55%)	4 (44%)
Foot position at IF (frontal plane)					
Pronation	29 (48%)	12 (48%)	11 (73%)	1 (9%)	5 (56%)
Supination	1 (2%)	1 (4%)	/	/	/
Neutral	9 (15%)	6 (24%)	/	2 (18%)	1 (11%)
Unsure	21 (35%)	6 (24%)	4 (27%)	8 (73%)	3 (33%)
Foot rotation at IF (transverse)					
Externally rotated	42 (70%)	19 (76%)	11 (73%)	6 (55%)	5 (56%)
Internally rotated	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Neutral	5 (8%)	3 (12%)	1 (7%)	0 (0%)	1 (11%)
Unsure	13 (22%)	3 (12%)	3 (20%)	5 (45%)	3 (33%)

IC, initial contact; IF, injury frame.

reported the actions of NBA players during ATR and found most injuries to occur during take-off/acceleration (8/12), with few during pivoting (2/12), jumping (1/12) and landing (1/12).[12] These results are partially in line with our study. Here, three patterns predominated. Acceleration from standing was the most common. Stepping backwards the injured leg while accelerating is the typical feature of this specific pattern when the player is trying to anticipate an opponent with a 'stop and go' movement. These injuries typically show a low horizontal velocity and are purely non-contact in 100% of cases (table 2). Given the low speed of these injuries, tendon tissue quality should be considered. The possible presence of tendinopathy, thus reducing the load tolerance of the Achilles tendon, must be considered.[20] This information was unknown in this study but still represents a factor that should be underlined in the overall interpretation of ATR.

A peculiar feature of football may be the high number (25%) of ATR injuries occurring during cross-over cutting. Cross-over cuts are associated with changing direction towards the injured limb,[21] while accelerating or maintaining velocity, in which the foot moves medially towards the mid-line. This contrasts with the side-step cut,
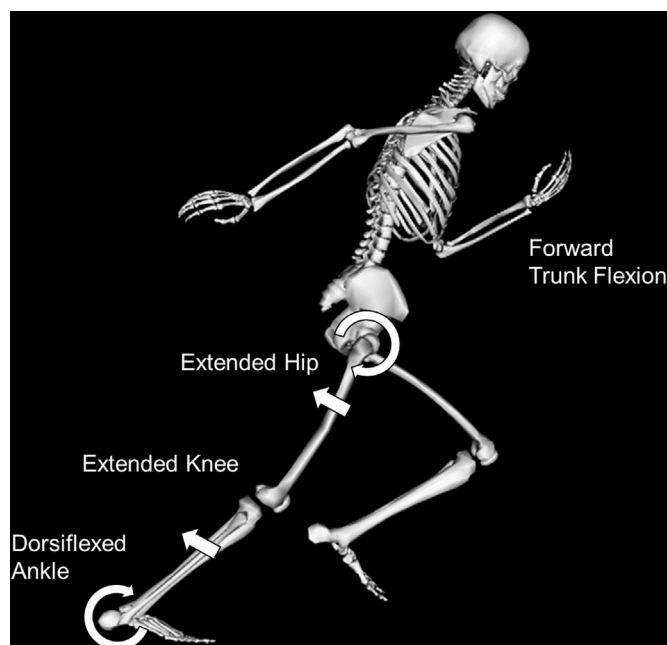
Figure 5 Biomechanics of ATR. Most frequent intersegmental positions at injury frame. ATR, Achilles tendon rupture.

which involves large levels of deceleration,[21] a braking action before reaccelerating at different angles with the foot moving laterally to the mid-line, typical of ACL injuries.[22 23] These injuries typically display high horizontal velocity and are also non-contact in 93% of cases. The medial positioning of the cutting foot to the COM may increase the loading on the AT through a multiplanar loading, including an increase in medially directed ground reaction forces, resulting in foot pronation. This newly described high-speed pattern may serve as a model for future studies to understand better ATR in football and other team sports.

Finally, jumping is the third described pattern with a component of vertical acceleration. Players frequently sustained a mechanical perturbation with a prevalence of 45% indirect contact injuries. These injuries happened in duel-type interactions, typically immediately before heading, with the injured leg stepping backwards while jumping.

Biomechanics

All injuries happened in closed kinetic chain (CKC) with the injured leg being loaded, forward displacement of the COM with an increase in hip and knee extension and abrupt increase of ankle dorsiflexion, indicative of acceleration position before forward or vertical propulsion. We also described a non-negligible role of multiplanar loading at the foot level, with foot pronation and external rotation being the most frequent findings when considering the foot and ankle complex. This is in line with a recent in-depth case report, whose biomechanical analysis reveals a potential role of frontal-plane internal moments.[24] While the focus has always been on the sagittal plane, these findings are interesting from various perspectives, including the possible injury reduction measures: prevention programmes could, therefore, be directed at counteracting the forces driving to the injury mechanism; this can be done by designing exercises, which train the athlete to limit and control foot pronation and excessive ankle dorsiflexion, thus allowing safer active sports actions.

ATR occurs when the mechanical limits of the tendon are overcome by high internal muscle forces.[25] The triceps surae muscle group has recently been shown to be an important contributor to force generation during propulsion tasks.[26] Just before the take-off, when the foot is planted in dorsiflexion, the calf muscle produces an eccentric contraction to prevent falling over the planted foot. At this time, energy is stored in the AT as elastic energy, which ultimately assists in propulsion in a stretch-shortening cycle. The measured dorsiflexion angles (40°) were close to or even more than the range of physiological weight-bearing values.[27] Thus, they indicate high forces with the muscle elongated and the AT stretched. Although the AT is the largest and strongest tendon in the human body,[28 29] explosive propulsion tasks are thought to result in forces of around 6–8 times body mass
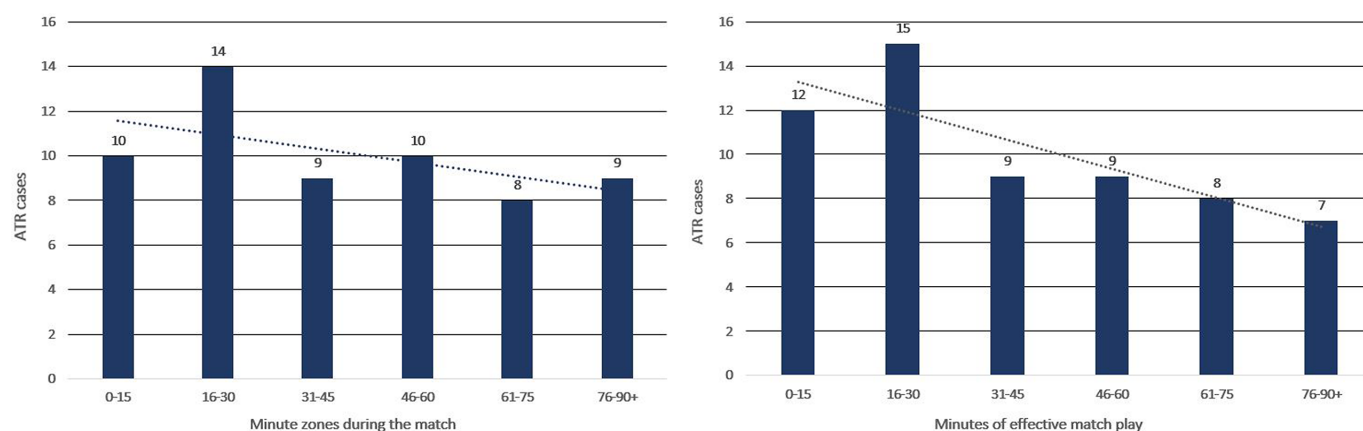
Figure 6 Distribution of ATR during the match play. (A) Distribution across minutes zones (15 min) of the match. (B) Distribution of injuries according to effective match-play, corrected for substitutions. ATR, Achilles tendon ruptures.

transmitted via the AT, potentially exceeding the ultimate tensile capacity of the tendon, resulting in ATR.[30]

We reported a high incidence of foot pronation during ATR, particularly during cross-over cut (all cases with identifiable footage). A certain degree of foot pronation is necessary for shock absorption and effective movement to be performed. Still, excessive pronation can create a whipping or torsional action on the AT, stressing the mid-substance. Excessive pronation in running has been associated with Achilles tendinopathy[31–33] and likely increased AT loading during the task, particularly during cross-over cut, that ultimately can be considered a model for AT loading.

When do ATR injuries happen?

There appeared to be a similar distribution of injuries across the first and second halves of the season, suggesting no seasonal impact of ATRs in football. Previous research on football injuries[34] has reported a higher incidence and risk during preseason and early season.

The similar number of injuries across both halves, with nearly half of ATR occurring in the first 30 min of effective match time, suggests that cumulative workload (and, in turn, fatigue over the course of match play)[35] was not a risk factor for injury. No other research has reported ATR distributions across the match. Factors other than cumulative fatigue likely contribute to ATR, such as the intensity of actions earlier in the match (eg, jumping higher or accelerating faster). For example, a second-half drop in the frequency and distance spent accelerating (and decelerating) at high intensity.[36 37]

Methodological considerations and limitations

A key strength of our study is its novelty, being the first video analysis study of ATR in football players. Only one previous video analysis study exists on NBA players with a small sample size (n=12)[12] and limited data analysis. The consecutive nature of the injuries analysed and the consistent biomechanical/kinematic analysis of three independent viewers using measurement tools is an additional strength. However, the methodology used to identify ATR injuries differed from the gold standard, which involves prospective studies with frequent contact with the teams.[18 38] Additionally, the model-based image-matching technique is considered the gold standard method of biomechanical analysis[22 24]; however, the goal of the current study goes beyond biomechanics and lies in the global description of ATR in football. Video analysis was consistently adopted in many previous studies on ACL,[6 9 17 18] MCL,[10] ATR[12] and concussion.[11] Finally, as we excluded training injuries and match injuries without identifiable video footage, we acknowledge that this the analysed sample might not be fully representative of the whole spectrum of ATR injuries in football.

CONCLUSION

ATRs in professional football are predominantly non-contact injuries, which occur according to three main patterns: acceleration from standing, cross-over cutting and vertical jumping. The biomechanics of ATR was consistent with a multiplanar loading of the Achilles tendon, consisting of a hip and knee extension, with the ankle in end-range dorsiflexion and the foot in pronation. ATRs appear to be unrelated to the period of the season nor the accumulated workload over the course of match play.

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