WHAT GETS MEASURED GETS MANAGED

BIOMECHANICAL AND ON-FIELD MEASUREMENT IN ATHLETIC GROIN PAIN

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INTRODUCTION

We wrote this overview around a simple premise: what gets measured gets managed. If we only measure strength and pain, we can only manage strength and pain. The tasks that provoke groin pain in football are dynamic and multidirectional, and they are the ones we measure least.

That is not a criticism of clinical examination or hip strength testing. Both remain the foundation of good practice. But they describe the injury and the athlete's load-bearing capacity rather than the way that load is produced, and no strength score tells you how the groin is loaded when a player jumps, runs, cuts or brakes at speed.

The "Aspetar groin pathway" sets clinical, laboratory and field milestones for progressing an athlete from injury back to performance.[1] Those milestones tell you when to progress. They do not tell you how the athlete is moving while they do it, and no systematic review covers jumping, running and change of direction biomechanics in this population. This article is the movement layer underneath the milestones. At each level of the pathway we ask what it shows, what it misses, and which variables add most to assessment and rehabilitation.

Two presentations run through the article, following the pathway's own distinction. Acute groin injury is primarily a tissue-healing problem; athletic groin pain (AGP) is primarily a load-tolerance and movement-strategy problem, and the two often coexist.[1] We use football as the reference sport, because it carries the highest exposure to the injury mechanism and is the setting where the directional demands of the game can now be measured at scale.

How strong is the evidence? We are not aware of a trial comparing rehabilitation with and without a movement layer, so nothing yet shows that measuring movement reduces recurrence. The strongest support comes from King and colleagues, whose work is set out in Part 1: rehabilitation built around movement improves symptoms and mechanics together, across a range of anatomical diagnoses. That is a rationale, not proof.

A word on equipment

Movement can be measured in many ways. Three-dimensional motion capture with force plates remains the reference standard, but markerless systems, two-dimensional video, inertial sensors and smartphone applications now put much of the same information within reach of a clinic, a gym or a pitch. Accuracy falls as accessibility rises, and the pathway itself asks for change of direction technique to be analysed with whatever equipment is available, from 3D motion capture to video[1]. We have therefore written this article around the variables rather than the hardware, so readers can look for what matters with the tools they already have. Almost none of the differences described below can be seen with the naked eye.

PART 1. LAB MEASUREMENTS

These methods let us quantify how a task loads the groin, compare athletes against uninjured controls, and track changes after rehabilitation. The research points one way: athletes with groin pain do not

all move the same, and their movement strategy does not necessarily match their anatomical diagnosis. Uninjured athletes do not all move the same way either, so the comparison is not against one correct pattern but against the range seen in healthy players and, where possible, the athlete's own uninvolved side. This is where movement assessment adds to what a structure-based model can tell you.

1.1 Jumps and landing

Jump and landing tasks expose the athlete to rapid force production and absorption, usually on one limb. Task selection changes what you learn: a bilateral jump describes global output, a single-leg drop landing adds load acceptance, and lateral hurdle hops add direction and repetition.

During **lateral hurdle hopping**, athletes with groin pain show reduced ankle plantarflexor contribution, altered knee extensor moments, and reduced hip extensor and abductor moments[2]. Repeated hops add longer contact time, lower peak vertical force and reduced rate of force development[3]. Rehabilitation shifts some of this but not all: jump height, ankle flexion, hip moments and hip rotation power improve, while contact time and some ground reaction force variables stay different from controls[4]. Movement variability does not differ between groups[3], so the problem is not inconsistency. It is the magnitude and distribution of loading.

During a **single leg drop landing**, athletes with AGP land with greater pelvic lateral tilt, more hip abduction and more hip external rotation than controls, with no sagittal-plane differences[5]. Footballers with hip and groin pain also differ in mediolateral margin of stability during a **single leg drop jump**[6]. The differences are small, but symptomatic athletes appear to prioritise mediolateral control through a more conservative landing.

Output metrics can miss the problem entirely. Elite female footballers with a history of groin pain showed no measurable strength or **countermovement jump** deficit, yet still reported lower HAGOS pain and sport scores[7].

Take home. No single jump task represents the whole problem. Pair a bilateral output measure with a single-leg landing task, because output can look normal while frontal-plane pelvis and hip control does not.

1.2 Running

Running exposes something different from jumping: how the hip and adductor musculature cope with the same demand repeated thousands of times across a match.

Hip Muscle Forces and Work During Running

During running the hip musculature works in a phase-specific way, holding frontal-plane pelvic control while generating sagittal-plane propulsion. Modelling shows a clear hierarchy, with gluteus medius producing the greatest peak force of any hip muscle to stabilise the pelvis during stance[8]. The adductors stay active across swing and stance; EMG-driven estimates in walking show sustained activity contributing to frontal-plane stabilisation and limb tracking[9]. Adductor magnus is the exception. It works out-of-phase with the other adductors and instead works with the hip extensors, contributing to extension rather than acting purely as a frontal-plane adductor. Its torque-generating capacity is roughly twice as large for extension as for adduction[10].

Modelled hip contact force during running peaks once per cycle, rising from

roughly 7.5 body weights at 6 km/h to 10 times at 12 km/h[11]. These are jogging speeds; equivalent data do not exist at sprinting speeds, so match loads remain unknown. Of the frontal-plane variables tested in healthy adults, hip adduction moment shows the strongest association with peak hip contact force, which is why it is used as a surrogate[12].

Muscular work also redistributes with speed. Below about 5 m/s the ankle plantar flexors dominate propulsion; above it the hip extensors, including the ischiocondylar portion of adductor magnus, take over as the primary energy generators[13]. In sprinting the adductors face heavy eccentric deceleration then rapid concentric acceleration, and modelling suggests maximum speed is highly sensitive to adductor longus and magnus capacity[14].

Groin pain and running mechanics

Absolute hip adductor weakness is the key modifiable risk factor for future time-loss groin injury, whereas relative measures such as the adductor-to-abductor ratio show no significant association[15]. Structural disruption of the posterior inguinal wall, external oblique aponeurosis or conjoint tendon alters the force-couple across the pubic symphysis and with it the pelvic loading environment during locomotion[16]. Match-play injury rates are 6.5 times higher than training[15], consistent with the high-load multidirectional actions that concentrate eccentric stress at the pubic insertions.

Athletes with groin pain move with restricted hip range. They show significantly smaller peak hip flexion angles during single-leg tasks, and this correlates with concurrent hip abductor weakness (r = 0.47)[17].

Take home. Running loads the adductors cyclically rather than maximally, and the adductor magnus behaves as much like an extensor as an adductor. Assessment should target frontal-plane pelvic control and ankle push-off power, taken from a running gait analysis at two or three representative speeds rather than at every speed the equipment allows.

1.3 Change of direction

Movement patterns and consistency

Cutting is often the provocative action in athletes with groin pain. Franklyn-Miller et al[18]. assessed athletes with AGP during a maximal-effort planned 110° cut and identified three movement clusters: knee-dominant, hip-dominant, and a third with greater ankle work, more dorsiflexion and longer contact time. These strategies were unrelated to the clinical diagnosis of the painful structure. Two athletes with the same diagnosis could load differently, and athletes with different diagnoses sometimes moved in the same way.

Moving differently does not mean moving inconsistently. Athletes with groin pain and healthy athletes both show high consistency across repeated cuts; it is the preferred strategy that differs[19].

Early phase COD biomechanical assessment

High-speed cutting is not the only way to detect altered strategies. Easier tasks with a COD component reveal multi-joint changes too[20,21]. During a **step-down followed by a 90° pivot**, footballers with hip and groin pain used a straighter pivot limb, with less hip and knee flexion, delayed hip flexion initiation and increased ankle plantar-flexor moment; the swing limb showed reduced hip flexion moment and delayed hip adduction[21]. These are not errors visible to the naked eye. They are subtle, coordinated changes across the kinetic chain, which is why they need instrumented measurement rather than observation.

Neuromuscular studies tell a similar story. During repeated **90° pivot turns**, athletes with AGP turned more slowly and showed lower trunk muscle activity, altered co-contraction between the internal oblique/transversus abdominis and multifidus, and changes in adductor longus and gluteus medius activation[20]. Groin pain is rarely only a local adductor problem. It is often a trunk, pelvis and hip coordination problem expressed during sport-specific movement.

Residual deficits – altered patterns during COD

Athletes can return to sport with altered cutting mechanics while pain-free. Australian footballers with a **history of groin pain** cut differently during an **unanticipated 45° task**, with less knee flexion, less hip internal rotation and higher ground reaction forces[22]. Saito et al[23]. found no difference in external forces but altered muscle contributions across the phases of a cut. Pain-free is not the same as recovered.

> ***If we only measure strength and pain, we can only manage strength and pain. The tasks that provoke groin pain in football are dynamic and multidirectional, and they are the ones we measure least.***

Rehabilitation can change these patterns. Before it, athletes rotate the pelvis poorly toward the intended direction of travel, hold a cautious upright posture and reduce ankle push-off power in late stance; dorsiflexion, plantar-flexor moments and push-off power are restored afterwards[24]. King et al[25]. rehabilitated 205 athletes with a programme targeting intersegmental control, running and COD mechanics. HAGOS scores improved, 73% returned to play pain-free at a mean of 9.9 weeks, and load was redistributed during the cut, changing trunk side flexion, pelvic rotation, knee flexion and ankle plantar-flexor moments, across a range of anatomical diagnoses. With no control group, that shows what is achievable rather than what caused it. These changes happen without any change in cutting time or contact time[24], so a stopwatch will not show you whether they have occurred.

Take home. Cutting is the task closest to the injury mechanism, and the strategy an athlete uses is not predicted by their diagnosis. Test the cut rather than assume it, and judge the result on movement strategy, not on cutting time (Figure 1).

PART 2. ON-FIELD MEASUREMENT

Everything so far has been measured indoors. Those tests tell us whether an athlete is ready to return to the pitch, not what happens once they get there.

2.1 What the game actually demands

Start from the injury, not from the GPS report. In football, acute adductor longus injuries occur most often during change of direction (35%), then kicking (29%), reaching (24%) and jumping (12%), and 71% happen without contact[26]. Those actions fall into two mechanical activities. Closed-chain actions load the planted limb in hip extension, abduction and external rotation and account for 59% of injuries; open-chain actions, where the hip switches rapidly from extension to flexion and abduction to adduction, account for the other 41%[26]. Groin pain covers several distinct entities[27] and previous injury remains the strongest intrinsic risk factor[28], but the on-pitch question is the same for all of them: has this player actually been re-exposed to the football movements that caused the injury? Answering it means measuring both activities.

The critical cutting scenario

Among the closed-chain actions, the scenario that most plausibly reproduces the injury is not a single angle. It is an interaction of angle, entry speed, braking, hip position, exit acceleration, predictability, repetition and fatigue[29,30,31,32]. Fast 60 to 90° reactive cuts and 90 to 180° high-braking turns dominate it, and braking impulse, contact time, hip abduction and trunk-pelvis reorientation all rise with angle.

In short:

High-speed entry → abrupt braking → injured limb plant → hip abduction/external rotation + trunk-pelvis rotation → 60–90° reactive cut or 90–180° turn → maximal exit acceleration → repeated under fatigue.

This is what rehabilitation has to build back up to (Figure 2, top banner).

2.2 What we measure today, and what it misses

Almost no team can tell you whether a player has actually been re-exposed to those movements, because on-pitch rehabilitation is still measured as distance, high-speed running totals, sprint counts

	JUMP & LANDING	RUNNING	CHANGE OF DIRECTION
TRUNK	↑ trunk side flexion	↑ trunk side flexion, ↑ unilateral trunk rotation	↓ trunk muscle activity, altered oblique and multifidus co-contraction, ↑ thoracic rotation
PELVIS / HIP	↑ pelvic lateral tilt, ↑ hip abduction, ↑ hip external rotation, ↓ hip extensor and abductor moments	↓ peak hip flexion angle, ↑ adductor magnus activity, ↑ pelvic drop midstance,	↓ hip flexion, ↓ hip internal rotation, altered adductor longus and gluteus medius firing
KNEE	↓ knee extensor moments		↓ knee flexion
ANKLE / FOOT	↓ ankle plantar-flexor contribution	plantar flexors dominate propulsion below 5 m/s; hip extensors take over above it	↑ ankle plantar-flexor moment, ↓ push-off power in late stance
	↑ contact time, ↓ peak vertical force, ↓ rate of force development. No sagittal-plane difference.	*Hip contact force 7.5 to 10.0 body weights at 6 to 12 km/h. Cyclical loading, not maximal.*	*Three strategy clusters, knee, hip and ankle dominant, unrelated to the diagnosis. Rehabilitation redistributes load without changing cutting or contact time.*

Groin pain is not a local adductor problem. The differences are multi-joint, they are not predicted by the clinical diagnosis, and no single task reveals all of them.

Figure 1: How athletes with athletic groin pain differ from uninjured controls across the three assessment tasks discussed in this section. Differences are distributed across the kinetic chain rather than localised to the adductors, and are not predicted by the clinical diagnosis of the painful structure.

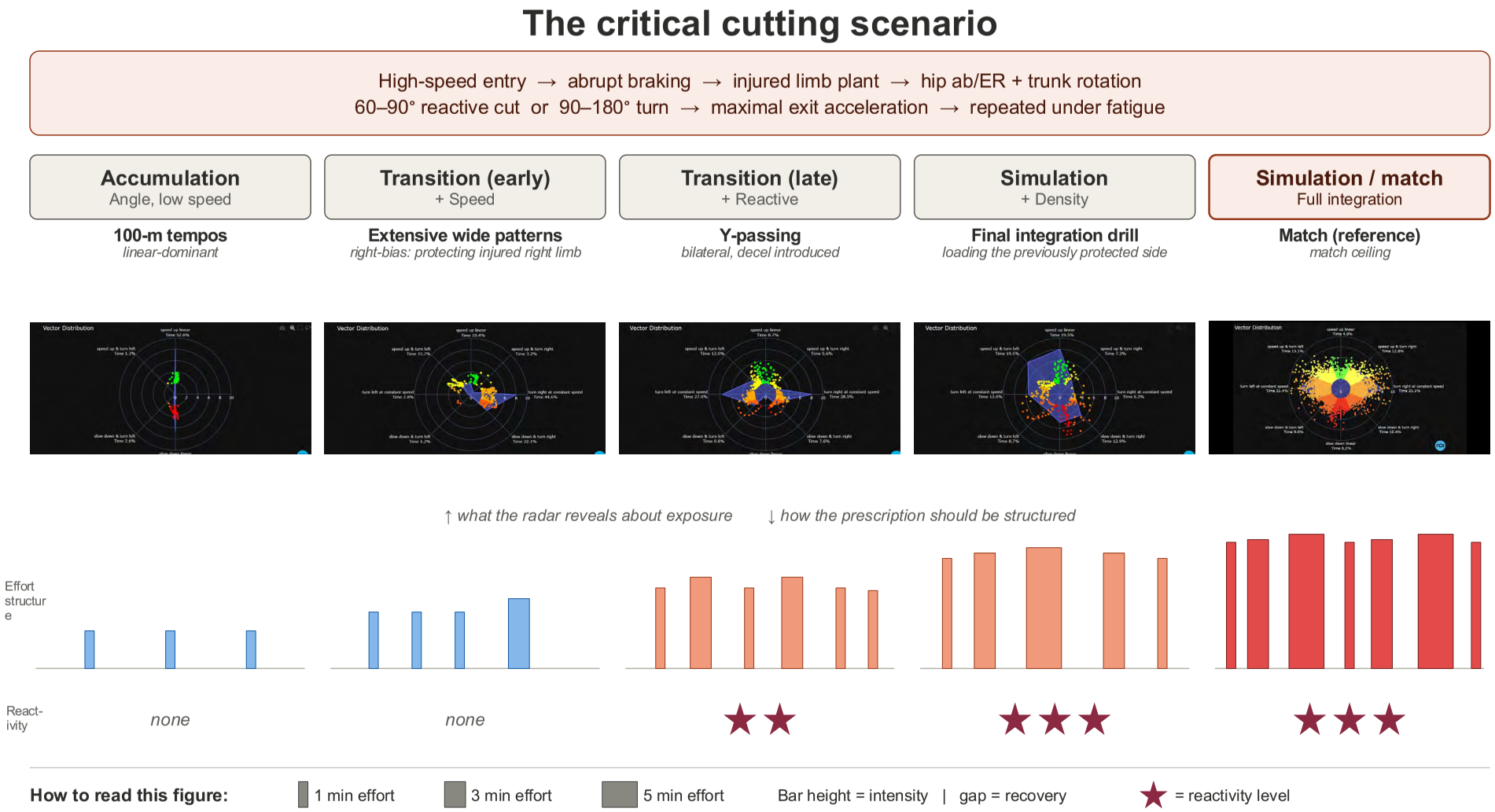

Figure 2: Checking on-pitch groin rehabilitation against the critical cutting scenario. Top banner: the destination rehabilitation must reach. Top row: one player's movement-signature radar plots across five drill sessions, spanning the Accumulation (rebuilding strength and running volume), Transition (high-speed running and drill-based training) and Simulation (game scenarios) phases of the Aspetar groin pathway, with the fifth panel the player's own match reference.1 Polygon shape encodes how time was distributed across eight movement sectors; percentages come directly from the player's GPS data. The sector data confirm the shape change rather than merely illustrating it: Accumulation is collapsed onto a single linear axis (52.6% speed-up linear, 43.6% slow-down linear); Transition (early) shows 44.6% turn-right against only 2.8% turn-left, the injured right limb protected from the planted, abducted, externally rotated position; by Simulation the asymmetry has been deliberately reversed (19.5% speed-up turn-left), and the match reference shows meaningful exposure across all eight sectors. Bottom row: prescribed effort structure, where bar height is mechanical work intensity, bar width is effort duration (narrow ≈ 1 min, wide ≈ 5 min) and bar spacing is recovery. Stars indicate the level of unplanned, reactive cutting required, rising from none in Accumulation to match-like in Simulation.

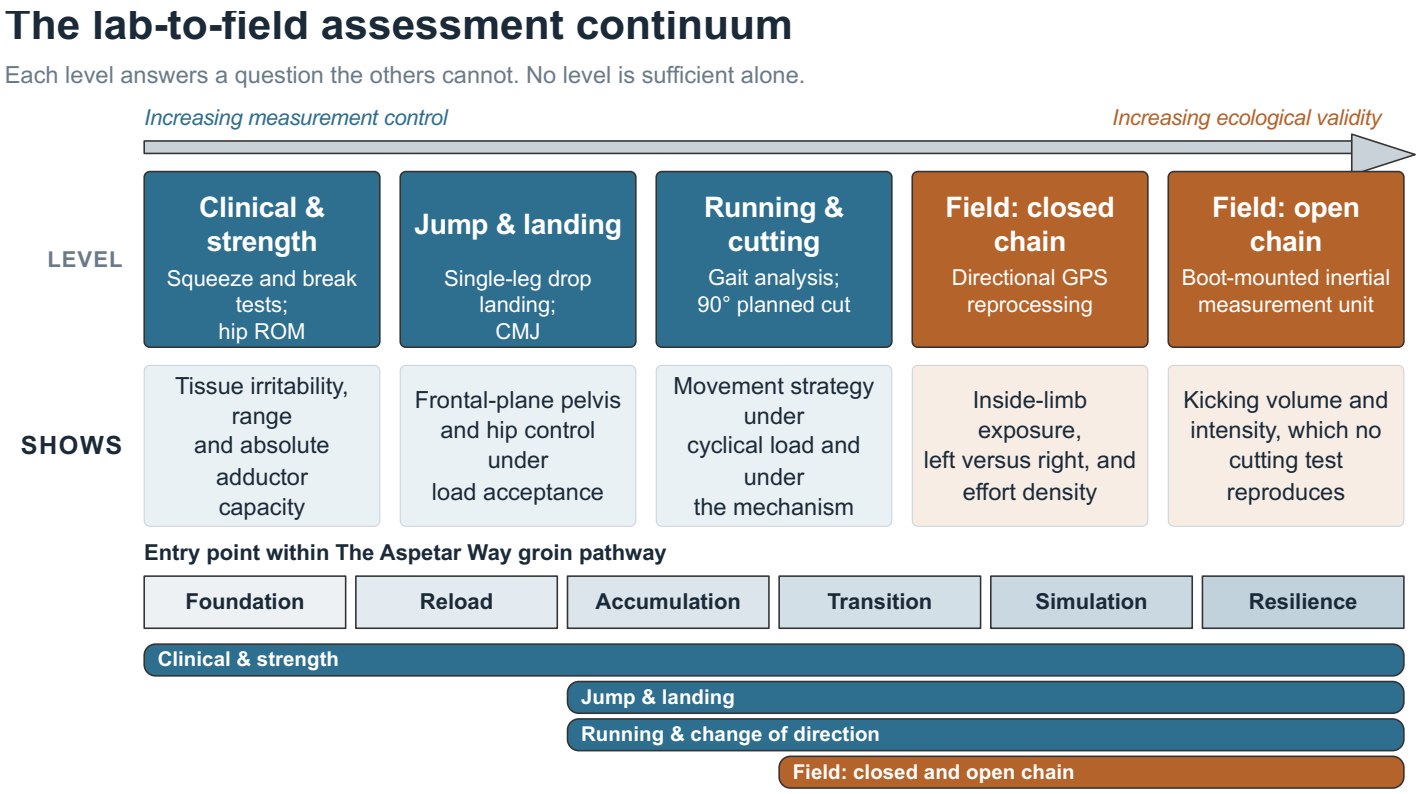

Figure 3: The lab-to-field assessment continuum. Laboratory and clinical testing gives the most control over measurement; field measurement comes closest to the real game. Each level shows something the others cannot, and the lower band shows where each enters The Aspetar Way groin pathway[1]. Table 1 gives the variables to prioritise at each level and the blind spot that goes with it.

and acceleration or deceleration tallies[33]. These describe locomotor volume, but none of them can tell one direction from another. They record how far, how fast and how many, not which way the player turned, braked or pushed off, and nothing at all about kicking. The pathway names this limitation itself: because the GPS metrics it references cannot tell the direction of a cut, cutting exposure has to be programmed carefully rather than measured, even though inside-limb loading during cutting and curved running is flagged as important before return to play[1]. A 90° cut left and a 90° cut right look identical on a totals dashboard, yet they load opposite plant limbs.

2.3 Making the demand visible

Running and cutting: the closed-chain half

Seeing these actions needs reprocessing, not new hardware. The raw signal from the GPS units players already wear can be split at every sample into tangential acceleration, along the direction of running, and centripetal acceleration, perpendicular to it. Each action is then classified into one of eight movement sectors: linear and curvilinear, accelerating and decelerating, left and right[34]. This matters because curvilinear running does substantial mechanical work even at constant speed, and linear summaries miss it entirely[35]. One implementation (Athletic Data Innovation, Hudl) recovers an extra 30 to 70% of multidirectional mechanical work in football[33]. The eight values can be drawn as a radar plot, one spoke per sector, spoke length showing how much work was done in that direction. It is a way of displaying the GPS data, not a new tracking device, and its shape shows whether the player has turned and braked in both directions.

Two components of the critical scenario cannot be read from the GPS signal at all. Whether a cut was planned or unplanned, and how fatigued the player was, are properties of session design rather than of the movement trace, so they have to be recorded separately.

Kicking: the open-chain half

Kicking is the second most frequent action at the moment of acute adductor longus injury, and it loads the adductors in an open chain pattern that no cutting test reproduces[26]. Directional reprocessing of GPS cannot measure this, but it is already programmed within the Aspetar groin pathway, where kicking is banded by demand and exposure is progressed band by band across phases (Table 1)[1]. Boot-mounted inertial measurement units supply the release velocity these bands depend on[36]. One caveat: independent validation supports kick detection more strongly than the velocity output[37], so release velocity is best read as change against the athlete's own baseline, which is how the maximal demand band is already defined.

2.4 Rebuilding the exposure, layer by layer

Once the demand can be measured, the progression can be reverse-engineered from it. The critical scenario is dissected and its components reintroduced one at a time, in an order that keeps the most dangerous stressors apart: angle before speed; speed added within each cutting pattern rather

Table 1

Level	*Recommended test*	*Variables we prioritise*	*What it cannot tell you*
Clinical and strength (prerequisite)	*Adduction squeeze and break tests; hip abduction and internal rotation range*	*Pain (NRS); inner and outer range adduction break LSI; hip abduction ROM LSI; absolute adductor strength, not ratios*	*Movement strategy under load. Covered by the pathway milestones rather than by this article. Adductor-to-abductor ratio shows no association with future injury*
Jumping and landing	*Single-leg drop landing; countermovement and drop jump for output*	*Lateral pelvic tilt and hip abduction at landing; contact time and reactive strength index; jump height*	*Direction-specific loading. Output can be normal while symptoms persist*
Running and change of direction	*Gait analysis at 12 to 16 km/h; 90° pre-planned maximal sidestep; unanticipated cut added in late Transition*	*Hip adduction moment and contralateral pelvic drop; ankle push-off power; plant width and trunk lean at final foot contact; movement strategy cluster*	*Absolute joint loading at football speeds; modelled data stop at 12 km/h. Strategy is not predicted by clinical diagnosis, so test rather than assume*
On-field, closed chain	*Directional reprocessing of GPS*	*Mechanical work by sector, especially inside-limb loading left versus right; effort density over 1, 3 and 5 min against match worst case*	*Reactivity and fatigue state. Both are properties of session design, not of the movement trace*
On-field, open chain	*Boot-mounted inertial measurement unit (e.g. Playermaker)*	*Kick count by demand band (medium >10 m/s, high >15 m/s, maximal >90% of baseline); injured-side release velocity trend*	*Hip position at ball contact. Absolute release velocity is less well validated than kick detection*

Table 1: Recommended tests and variables across the assessment continuum, aligned to The Aspetar Way groin pathway[1]. Variables are given in priority order. The final column states what each level cannot show, which is why the levels are complementary rather than interchangeable. All laboratory values are model outputs, not measurements, and several reported group differences are small relative to typical measurement error; interpret change against a known within-athlete error, not a published cut-off.

than as a separate linear drill; deliberate asymmetry away from the injured plant limb before bilateral exposure; reactivity while the player is fresh; and match-like effort density last[38,39,40]. A pure linear hard stop trains sagittal-plane braking and does not transfer to the frontal-plane control a 60 to 90° cut demands[38,39]. Adding reactivity before fatigue, and fatigue before density, stops the worst combination from being discovered on return-to-play day.

Figure 2 applies this sequence to one case, from the pathway's Accumulation phase1 through to the player's own match reference, and shows what the radar plot reveals at each step alongside the prescribed effort structure (Figure 2).

2.5 Measure, don't prescribe

The radar plot should check, not dictate. Drills are conceived from the football task, the player's symptoms and the rehabilitation phase[33]. It then verifies whether the intended mechanical environment was actually delivered. If three consecutive Simulation sessions produce a radar plot that still looks like Accumulation, the prescription has been linear regardless of what the coach intended.

One final check sits on top of the clinical and strength milestones[1,41]. Before clearing the player, rehabilitation should have reached the pathway's worst-case-scenario targets, so that the hardest 1, 3 and 5 minute passages of a session match what the player meets in the hardest passages of a match, with a radar plot matching or exceeding their own match reference on both sides, and maximal demand kicking on the injured side. That is the moment the critical scenario has been met in training rather than in competition.

Take home. What we measure on the pitch has to reflect the injury mechanism, and that means measuring both mechanical activities. Measure direction and inside-limb loading for the closed chain, kick count and release velocity for the open chain, and confirm both before clearance rather than after it.

Summary: Recommended Tests and Variables

Two views close the article. Figure 3 places the levels of assessment on one continuum, from clinical and laboratory tests, which give the most measurement control, to field measures, which come closest to the real game. Table 1 gives the variables we would prioritise at each level and what each level cannot tell you. Neither is a checklist: no single level answers the question alone, and the value of any measurement depends on knowing what it hides.

CONCLUSION

Clinical examination and hip strength stay central, but they are not the whole picture. Across jumping, running, cutting and on-field re-introduction the same pattern appears: athletes with groin pain move differently, the differences are subtle, multi-joint and not predicted by the diagnosis, and some outlast the symptoms.

Whether those differences caused the injury or followed it is still unknown. The

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Illustration

available studies compare athletes who already have pain, or have had it, so cause and consequence cannot be separated; only measurements taken before injury could do that. The practical implication is the same either way: a pattern still present once the pain has gone is still worth changing.

Our advice is this: Measure the movement, not just the muscle. Use the tasks that reproduce the mechanism, prioritise the variables that carry most information, and make sure the directional and open-chain demands of the game are delivered in training before they are met in competition. The pathway tells you when to progress; measuring movement tells you whether the athlete has earned it.

References
Available at www.aspetar.com/journal

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