PROACTIVE
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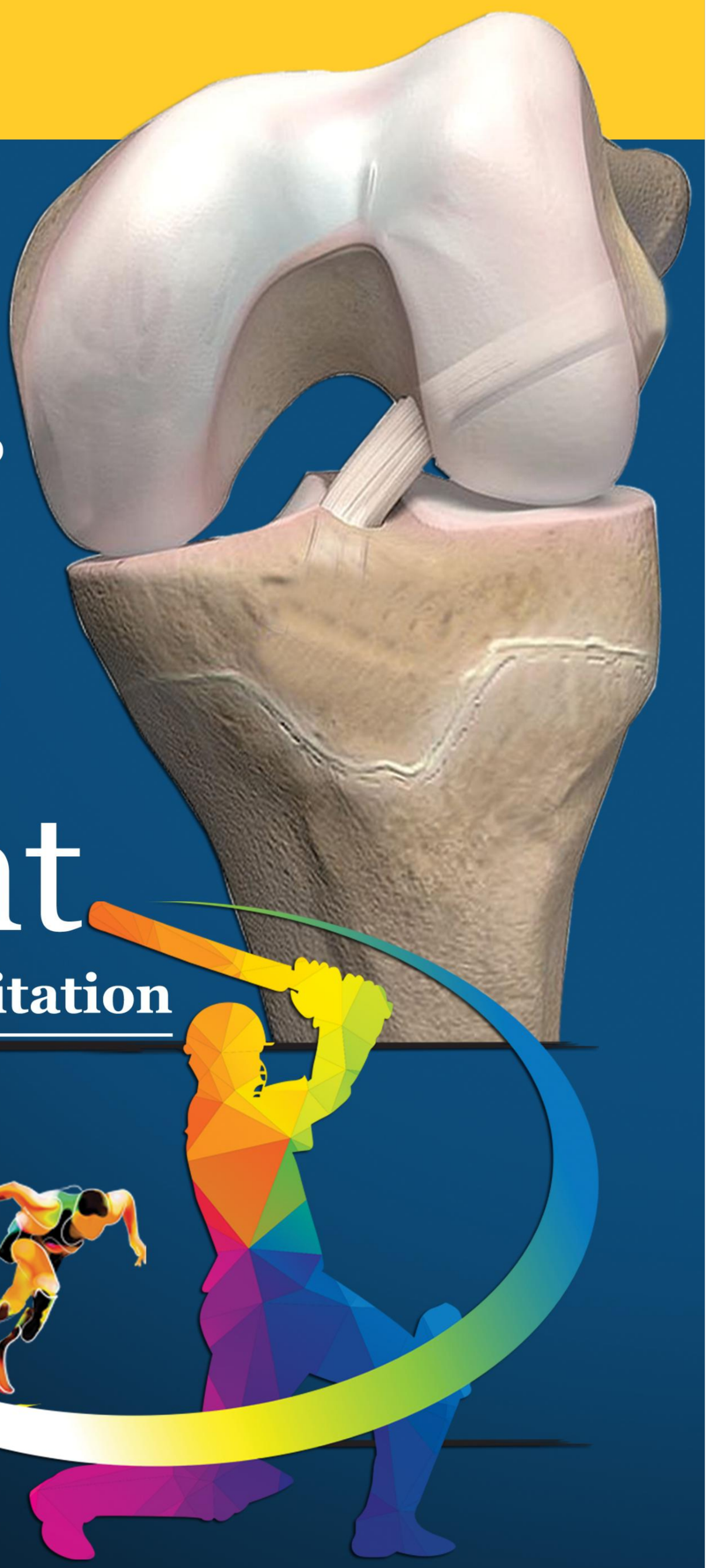

The Anterior Cruciate Ligament

Goal Oriented Rehabilitation

Jaymin H. Bhatt | Rosario D'onofrio | Hiten Panchal

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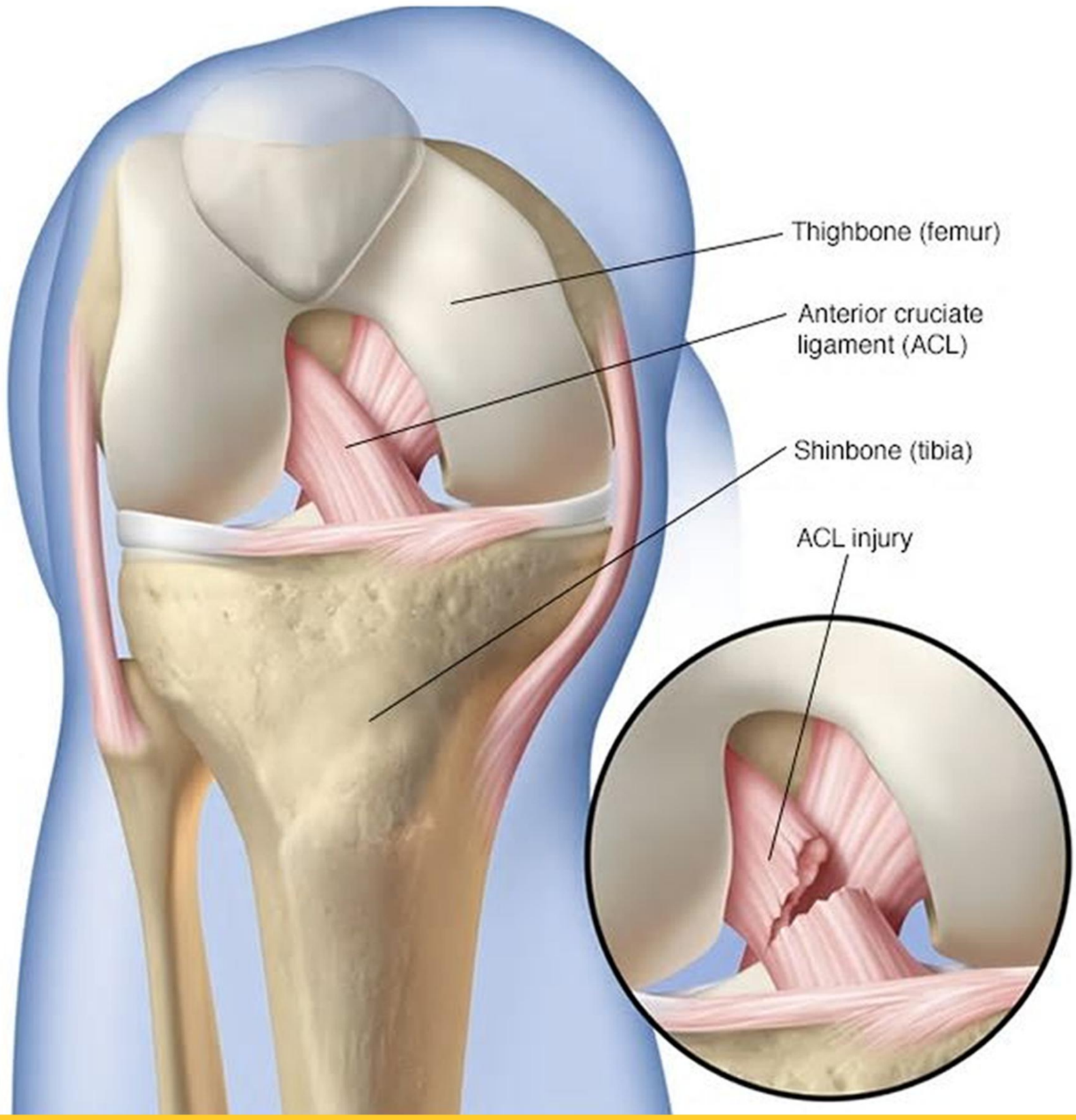

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INRODUCTION

JAYMIN H. BHATT

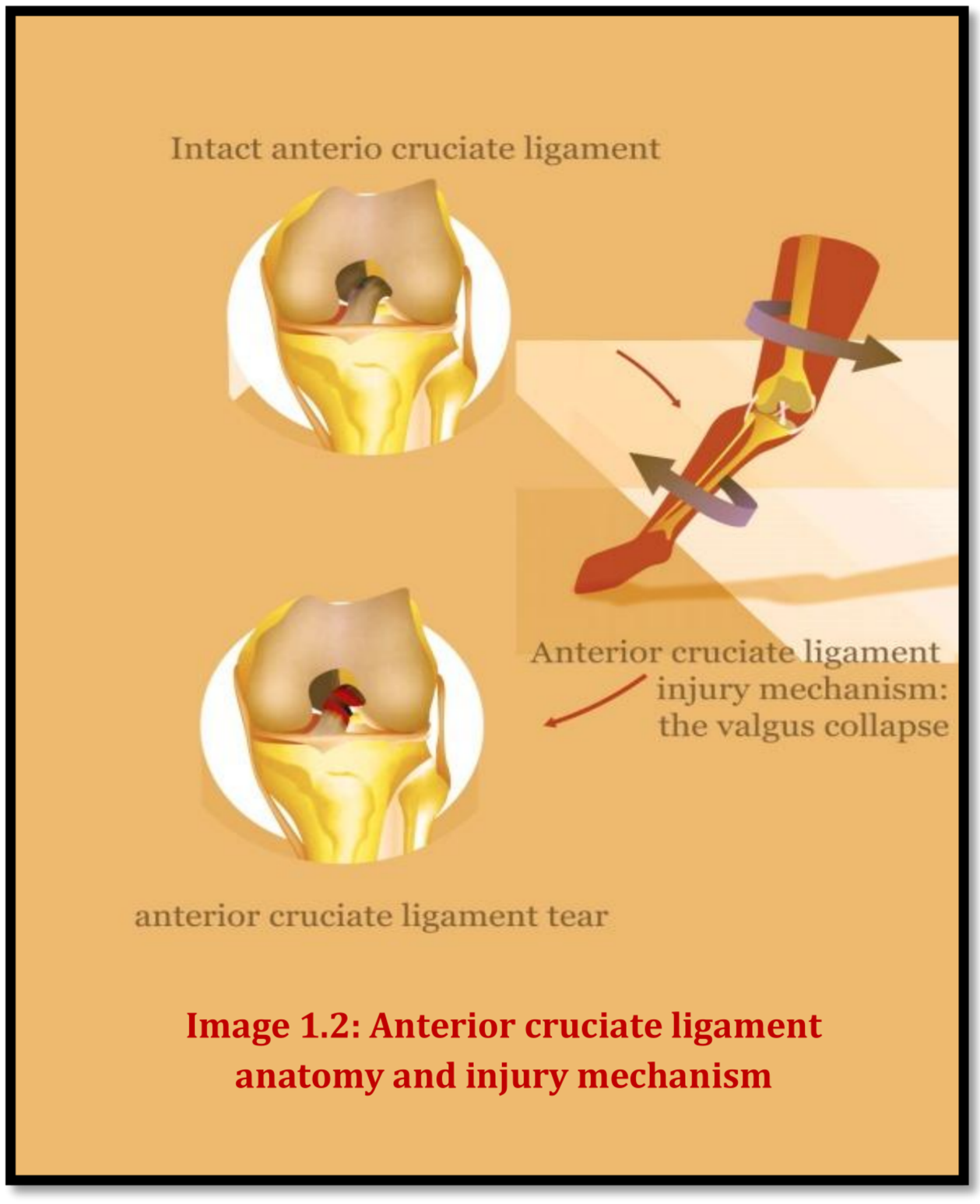


Image 1.2: Anterior cruciate ligament anatomy and injury mechanism

ACL INJURY MECHANISM AND ITS INCIDENCE

ACL tears are the most common ligament ruptures in the knee, with 70% of them occurring during a non-contact trauma [8]. There is a pre-dominant injury pattern is found in pivoting athletes: a combination of knee valgus, hip internal rotation and tibial rotation, called the valgus collapse (image1.2). When normally detect changes in tension, acceleration, direction of movement and knee joint position which is due to the loss of mechanoreceptors, Therefore, ACL deficiency causes partial de-afforestation and alters spinal and supraspinal motor control. The changes in motor control strategy can reveal changes in proprioception, postural control, muscle strength, movement and recruitment patterns.[9] (image 1.3) An ACL injury might therefore be regarded as a neurophysiologic dysfunction and not a simple peripheral musculoskeletal injury.[10,11] The incidence of ACL injuries in pivoting sports (e.g. soccer, handball, basketball) is high; 0.8-2.4% of male and 2.0-3.2% of female amateur athletes rupture their ACL during a season, with individuals aged between 15 and 45 years at most risk.[12,13]

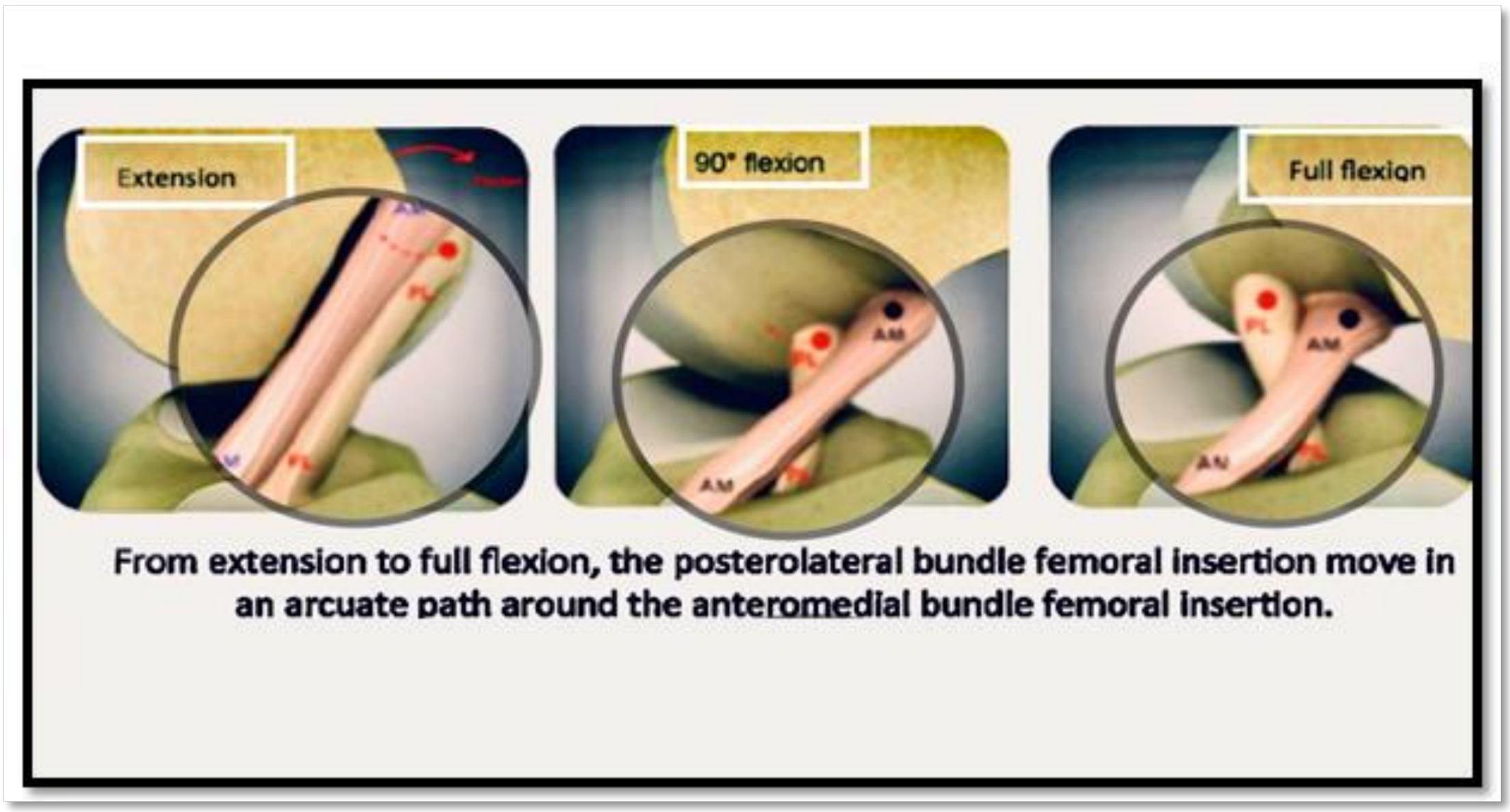
SURGICAL OPTIONS

An ACL injury results in reduced passive knee stability and loss of mechanoreceptors, which may contribute to functional instability. The most young pivoting athlete option for ACL reconstruction, To maximize knee stability and to avoid new knee trauma with possible additional meniscal or cartilage damage.[2,14] Bone-patellar tendon-bone (BPTB) and hamstring (HS) auto grafts are the most commonly used methods for ACLR, but the choice of graft type also strongly depends on the surgeon's personal preferences. BPTB grafts were most popular until about ten years ago, with HS grafts increasing in popularity thereafter.[14,15] There is only marginal differences in failure rates and residual symptoms between BPTB and Hamstring auto grafts shown

RECIPROCAL FUNCTION OF THE AM AND PL BUNDLE

The AM-bundle is found to be the longer of the two (bundles) – described variably as 28-38 mm long [40,48]. The shorter PL-bundle (about 18 mm long) is somewhat more horizontally orientated than the AM bundle in the intercondylar notch, but their relative position to each other does vary with the degree of flexion in the knee. (Image 2.3) Studies on the differential behavior of the AM and PL bundle describes their behavior throughout the knee range-of-motion. From extension towards flexion the AM-bundle tightens whilst the PL-bundle slackens [44] – towards extension, the PL bundle invariably tightens. In light of these findings, a "reciprocal action" of the AM and the PL bundle has been proposed[43]. By examining in-situ forces in the two bundles throughout knee flexion, the same tendency – of AM tension increase towards flexion and PL tension increase towards extension – has been found [46,47]. The ACL primary function, namely resisting anterior tibial translation has been described [45, 42]. The author found that the AM bundle had a dominant role at 90 degree of flexion, whilst the PL bundle was dominant at 20 degree of flexion[43] (Image 2.3) [60]

Image 2.3[60] Flexion and extension of ACL two Bundle



PLANE OF MOVEMENT

To prevent abnormal ACL loading during activities, It is important to understand which plane of movement can place harm or stress on the ACL which resulting in rupture. The ACL is not only associate with sagittal plane movement but Sagittal plane knee movement are frequently associated with place load on the ACL[35]. In addition, the ACL can also resist movements in the frontal plane. for instance, in knee valgus position the extreme amounts of valgus load place on the ACL. It can result in too much tensile force resulting in damage to the further structures. The well-executed sagittal plane movements typically do not produce abnormal ACL loads during landing or side-step activities[36]. It is also evident that in the frontal plane movement can contribute more to ACL injury than sagittal plane. The knee kinematic movements show that abnormal

The hamstrings are stabilizing the ACL. When the knee is near or full extension, quadriceps contraction increases ACL tensile force. They are often minimally contracted during these injuries, particularly if the hip is extended and the body weight is on the heel, allowing for excessive forward shifting of the femur on the tibia. Approximately 75% of ACL ruptures are sustained with no contact at the time of injury. When there is a sudden change in direction or speed with the foot firmly planted on the ground during contact sports. Rapid deceleration moments, including changing sudden direction which has also been linked to ACL injuries. Anterior shear forces from the quadriceps may play a role in ACL disruption. However, it is more likely that quadriceps contraction lowers the axial threshold of injury by increasing the compressive force on the knee. Thus, it is probable that the mechanism causing non contact ACL injury simulates the pivot-shift test in patients with ACL deficiency.

Clinical presentation

- Instability
- There may be an audible pop or crack at the time of injury
- A feeling of initial instability which may be followed by extensive swelling
- Episodes of giving way especially on pivoting or twisting motions.
- A torn ACL is extremely painful, particularly immediately after sustaining the injury
- Swelling of the knee, usually immediate and extensive, but can be minimal or delayed
- An inability to fully extend the knee
- Possible of tenderness
- Tenderness at the medial side of the joint which may indicate cartilage injury.

Palpation

1. Patellofemoral joint (including patellar and quadriceps tendons) (Image 1)
2. MCL (Image 2)
3. LCL (Image 3)
4. Medial joint line (Image 4 & 5)
5. Lateral joint line (Image 4 & 5)
6. Prone (e.g. hamstring tendons, Baker s cyst, gastronomies origins)

Image 1

Image 2

Image 3

Image 4 & 5

Stability testing

Physical examination typically displays a hemarthrosis if the injury is recent. Chronic ACL tears may also or may also no longer have an related effusion. Acutely, range of motion is usually impaired, mainly in flexion. This might also be due to a combination of pain and stiffness from hemarthrosis, as well as associated bone bruise, meniscal tears, or articular cartilage injury. Tenderness is located at the lateral femoral condyle and lateral tibial plateau.(indication type of injury)

THE LITERATURE The pivot shift test is technically more challenging to perform than the other 2 tests and is, therefore, less practical in the primary care setting. However, when this test is done correctly, a positive result is highly specific for ACL injury.8, 9 its reported sensitivity values are very contradictory. The most recent meta-analysis reports a sensitivity of 85%. 6 two other studies cite much lower values: 24% and 28%.8, 9. this information propose that the pivot shift test, when done accurately, can be useful in affirming an ACL rupture. In any case, the test ought not to be utilized alone in decision out for ACL damage.

LEVER SIGN TEST

The lever sign test[19] introduced in the mid-2010s is also performed with the patient lying in the supine position. The examiner stands at the side of the affected knee of the patient, places a closed fist just beneath the proximal third of the patient's tibia, creating a slight flexion of the knee joint. With the other hand, the examiner applies a downward directed force to the distal third of the femur. With an intact ACL, the patient's foot should rise from the table due to the induced lever mechanism. With a ruptured ACL, the lever effect is absent, and the foot will not rise.

THE LITERATURE In the prospective clinical study that introduced the lever sign test, the sensitivity rate was reported at 100%—higher than other commonly used tests.19 Another study has reported that the lever sign test was easily adopted in clinical practice and showed higher sensitivity than the Lachman test (94% vs. 80% in pre-anesthesia assessment).[20] However, a more recent study has shown a sensitivity of 77% for the lever sign.21 Based on research, The lever sign test is comparatively simple to perform and needs less examiner strength than the Lachman test. These factors enhance relevance of the lever sign test within the medical aid workplace and in alternative settings like physiotherapy centers and emergency departments.

RADIOLOGY

INTRODUCTION

ACL rupture is the commonest ligament us injury of the knee with a peak incidence in the second and third decades. The injury most commonly occurs in sports such as gymnastics, basketball and soccer. Following repair, the estimated re-rupture rate is between 1-11% [22]. In this chapter we will discuss the anatomy of the ACL along with the imaging features of primary ACL injury on conventional radiography, computed tomography and MRI. Imaging of ACL reconstruction will not be covered in this chapter.

IMAGING

The ACL is the most important structure in maintaining the knee joint biomechanics and is also the most commonly injured ligament. The oblique course of the ligament makes visualization and assessment of it challenging. The vast majority of ACL injuries are diagnosed by history and clinical examination, although in acute injuries pain and swelling limits diagnostic sensitivity. Imaging is usually required to confirm the clinical suspicion, extent and associated injuries to the knee joint.

Normal Appearances

The ACL has a striated linear appearance on both T1 and T2 weighted sequences due to the interposition of fat and connective tissue between the fascicles (Image 3.4). The AMB has lower signal intensity than the PMB on all sequences. The overall signal intensity of the ACL is higher than the posterior cruciate ligament (PCL).

The advantage of MRI compared to conventional radiography and CT in the context of ACL injury is that it allows direct assessment of the ACL (primary signs) and the surrounding bony and soft tissue structures (secondary signs) for associated injuries. Meticulous assessment of the various secondary signs associated with ACL injury enables one to predict the mechanism of injury.

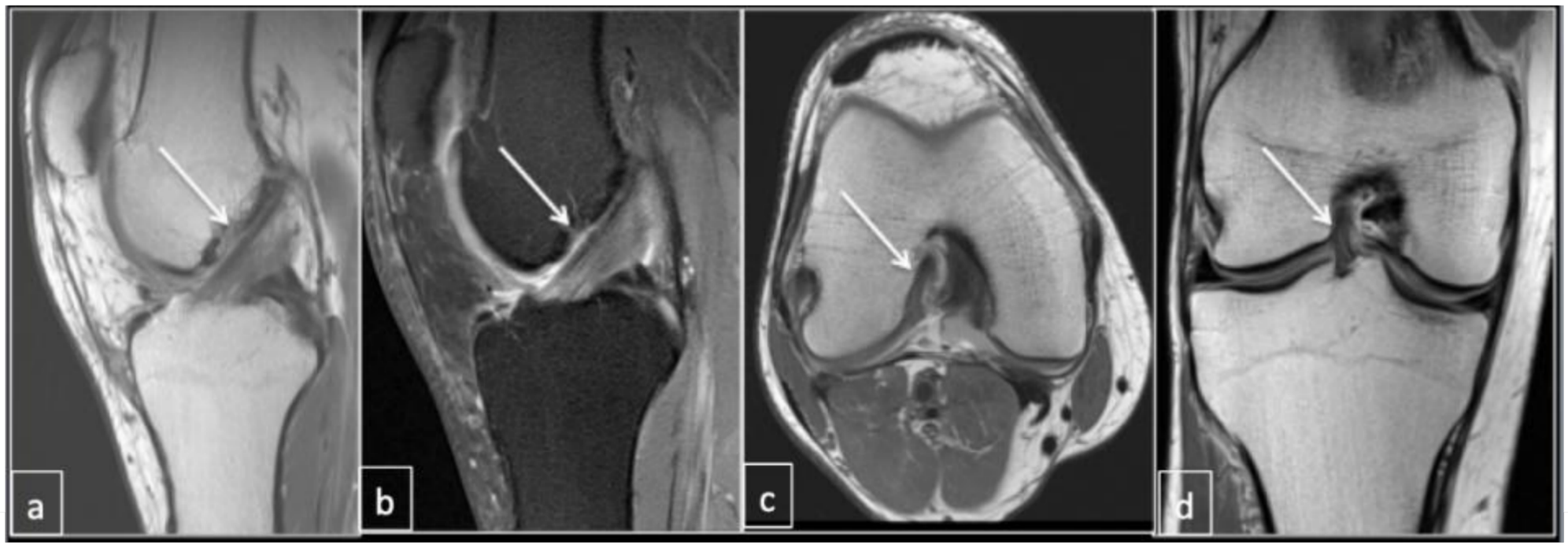
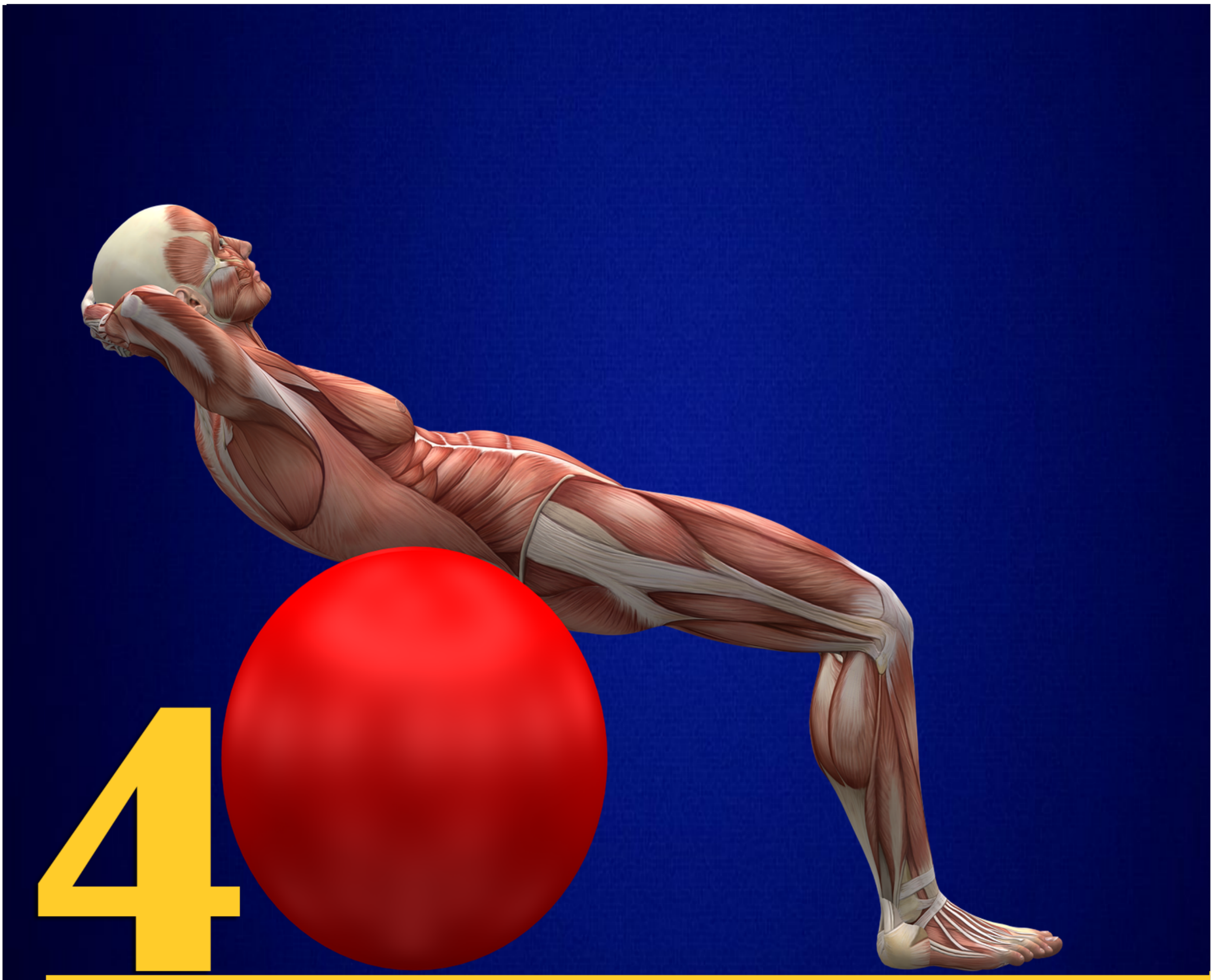


Image 3.4: Sagittal PD, PDFS, Axial PD and Coronal PD weighted images demonstrating the normal striated pattern of the ACL. Note the low signal anterior aspect of the anteromedial band.

Primary Signs

Although the mechanism of injury is the same for both, partial thickness and complete full thickness tears of the ACL, in partial thickness tears, the AMB is most commonly injured. Direct signs of a partial thickness tear include focal angulation of the ACL and loss of the normal striated pattern with intrasubstance high signal on fluid sensitive sequences without complete fiber disruption [46]. High-grade partial thickness tears are often found with other associated ligamentous, meniscal and osteochondral injuries.

The ACL is most commonly torn in its mid portion, although proximal and less frequently distal portions of the ligaments maybe torn (Image 3.5 and 3.6). The femoral attachment is weaker than the tibial insertion. Direct signs of complete ACL tears include replacement of the normal striated pattern with an amorphous cloud like appearance of high signal intensity and discontinuity of the ligament fibres that no longer parallel the intercondylar roof. Other features such as thickening, wavy or retracted appearance may also be visualized. T2-axial sequences are also useful in assessment of the ACL rupture with a sensitivity of 92% and specificity as high as 100%. High signal intensity on T1 and T2 weighted sequences at the expected location of the ACL represents oedema and haemorrhage [47]. The distal stump may displace anteriorly and may cause locking of the knee joint in extension. On sagittal images it appears as a nodular mass in the anterior aspect of the intercondylar notch [48].



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OPTIMISE PERFORMANCE WITH CLASS "A" REHABILITATION

**WE RECOGNIZE THAT GOAL BASED REHABILITATIONS FAR SUPERIOR TO TIME BASED REHABILITATION....
BUT BIOLOGICAL HEALING MUST ALSO BE RESPECTED"**

JAYMIN H BHATT

- Progress to restoration of muscle strength with intensive muscle strength training (increasing resistance, complexity and reps), and controlled polymeric exercises (eg balance board, progressing to squats on board)
- Running and jumping sports should be avoided due to risk of knee instability.

Criteria for recommending ACL surgery

A functional instability with complaints of giving way. In an acute situation, it is difficult to find out whether there is a functional instability is present during daily activities. Hence, we recommend to avoid ACLR in the acute situation, in order to minimize the chance of operating asymptomatic patients.[2,97] The knee has a minimal synovitis reaction,

- full extension
- good patellofemoral mobility (left=right),
- Actively control the quadriceps
- A correct gait pattern in order - prevent arthrofibrosis.[33,92,95,99,120,131]
- A quadriceps strength deficit compared with the healthy leg of
- Maximum 20%. A strength deficit of 20% or more predicts a significant strength deficit until two years after ACLR.[39,75]

"When there is a quadriceps strength deficit of more than 20%, use closed and open kinetic chain exercise to improve strength"

ACUTE RECOVERY - PHASE 1

In the acute period after ACL reconstruction the knee needs some time to recover from the acute trauma of surgery. Basic gentle exercises, regular application of ice and elevation of the knee are beneficial. Most will leave hospital using Walker, which should be used to achieve a normal gait pattern during the first week after surgery.

GOALS OF PHASE

- Minimise synovitis/effusion
- Restore range of motion
- Voluntry quadriceps control
- Active dynamic gait pattern, Progress to walk without walking aids.

	calculated by dividing the mean distance (in cms) of the involved limb by the mean distance of the noninvolved limb then multiplying by 100.	
Squat	1RM Squat Squat; whichever way you choose to do it, we advise that the person attempts to squat down to 90 degrees knee flexion, and rises up into full knee and hip extension	1.5% of body weight

GOAL

1. Establish proper running and jumping skills with good technique

2. Recovery of balance and agility

3. Progression of muscular strength and power

4. Gain confidence for return to sport and sports specific drills

The knee should be free of swelling and pain during this phase. Once sufficient strength is achieved during Phase 2, the emphasis should be focus on improving balance, agility and proprioceptive deficits. This phase is more important because ligamentization process is going on ,one should be very careful during this phase. It's important to teach perfect landing and pivoting biomechanics before progressing to next phase. Physiotherapist should improve the control of pelvic. However, ACL injuries have beenshown strongly associated with poor hip biomechanics.[42]. You can start with drills such as scissor jumps and single hops and progress to box jumps and single leg landings with perturbations.

MOBILITY

- Maintain full patellofemoral and tibiofemoral range of motion.[59]

STRENGTH TRAINING

- Intensify (sport) specific strength training

NEUROMUSCULAR TRAINING

- Proprioceptive work should include hopping and jumping activities and emphasise a good landing technique.
- Progressive single limb landing activities can be assessment and training tool eg anterior single leg hops, lateral single leg hops.
- Hops and jumps can progress by increasing height and complexity – add ball catch
- Agility work may commenced after basic running and progressed through activities such as shuttle runs, bounding runs, sideways running, skipping, etc.
- Emphasis on good form through change of direction drills and hopping,
- Feedback on good techniques using slow motion video from mobile device can be very beneficial for education.
- Commence basic components of PEP programme and progress

Wolf at al found that if you can add suprapostural task had a positive influence on the learning of a dynamic balance task. For comparison of two examples of instruction for practicing a postural control with an internal and external focus respectively presented in table 1 [49]

Example of internal and external focus for gain balance.

Internal Focus

External focus

Plyometric exercise: Alter hip and knee biomechanics during landing is the risk factor of second ACL injury. Hence, this needs to be address before athlete discharge from pivot type of sports. Motor learning with external focus has proven to be effective in the establishment of certain movement goal. However, ACL injury prevention training has specific goal towards the learning safe movement. There is literature which states that movement form can be improved when using external focus of attention. This attention illustrates by greater knee flexion angles[21]more towards Centre of displacement, lower ground reaction force.[22, 23].

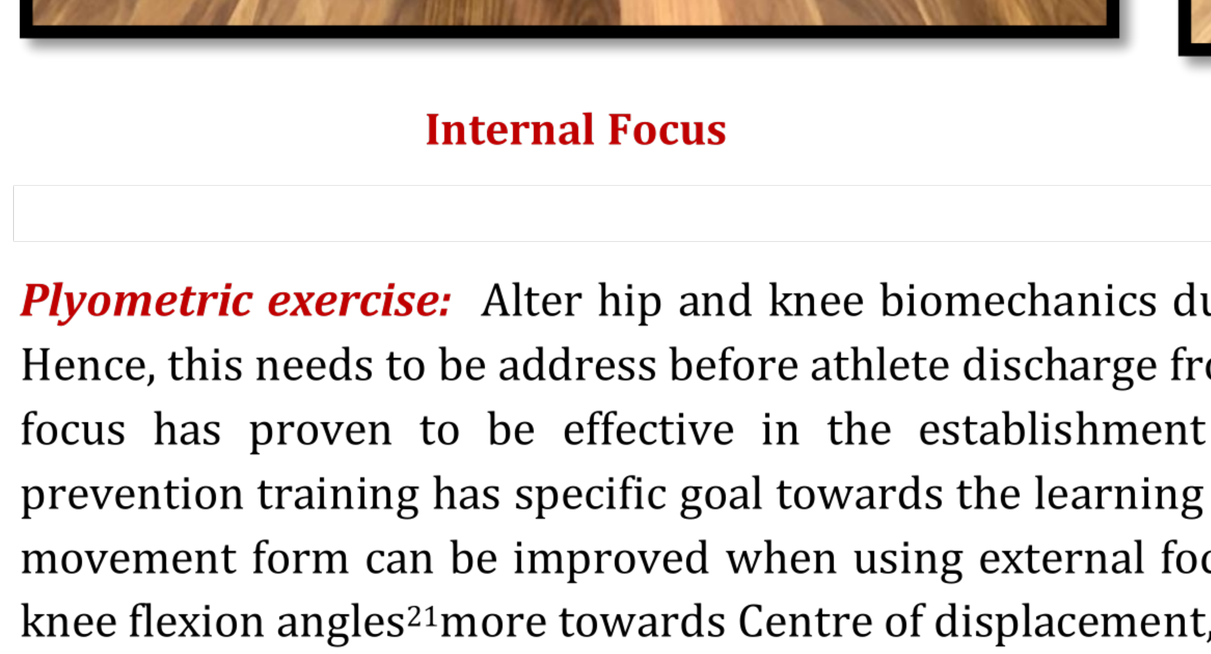


Image 5.5

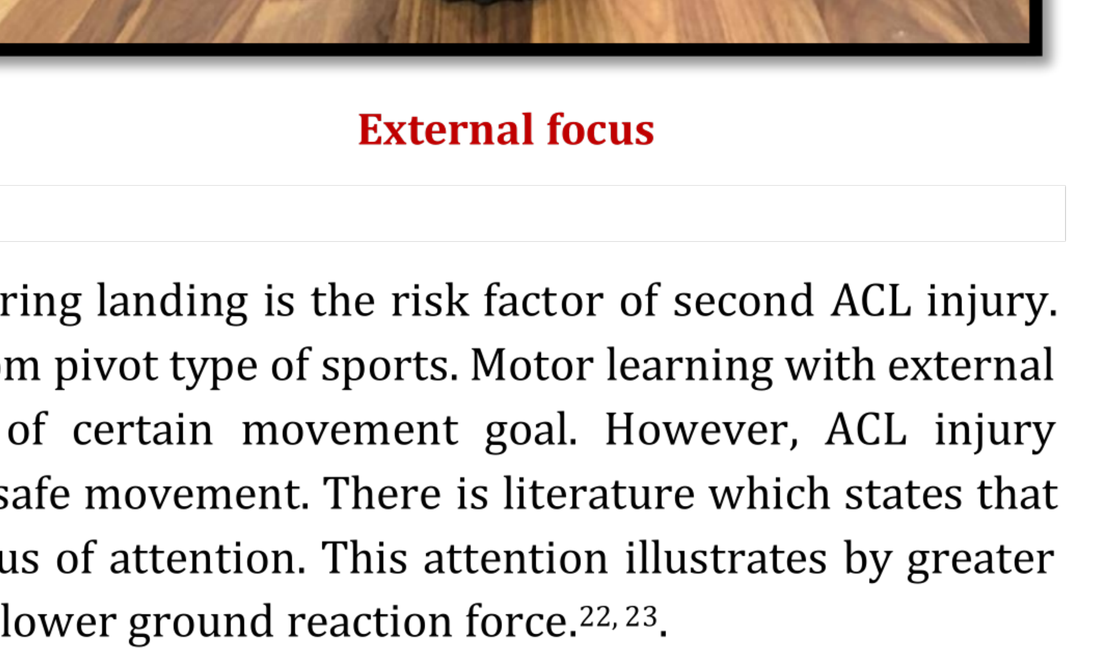


Image 5.6

content but will not reach normal ACL tensile strength until at least over a year (if at all). According to Rabuck et al, it would appear there may be a role for imaging to be involved with staging of the rehabilitation process in the future. As the ligament undergoes revascularization, MRI can potentially be used to detect the levels of revascularization and thus aid in determining the forces the graft can withstand at the tim**e.**

Selection of quadriceps exs:

Time-based quadriceps strength exercise prescription during the history of ACLR rehabilitation protocols. (Table 1)

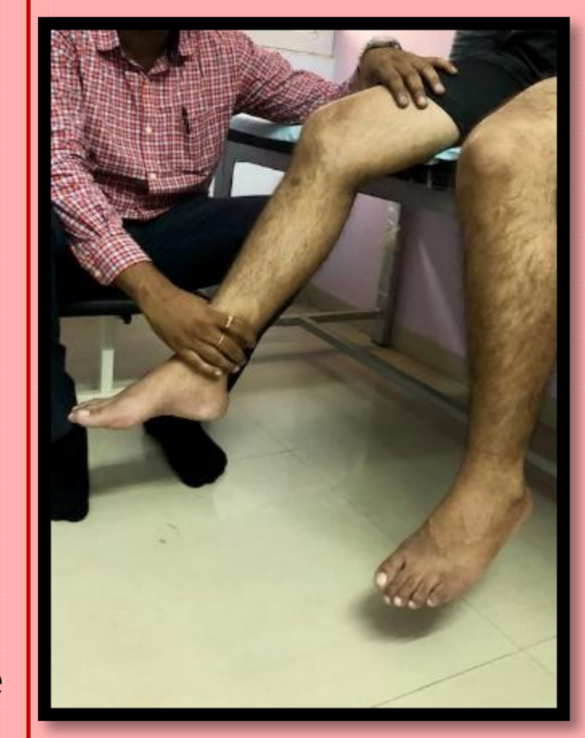
Week	Traditional rehabilitation, Shelbourne66	Accelerated rehabilitation, Shelbourne66	Neuromuscular & strength rehabilitation, Risberg62	Evidence-based rehabilitation, van Grinsven30
1	Active straight leg raise	Active straight leg raises	Active straight leg raises; 4x 20-30 repetitions	Active straight leg raises; OKC exercises ROM 90-40°; CKC exercises ROM 0-60° (squats)
2-4	Leg extension 90-60° without resistance	Add step up, leg press and squat		OKC exercises from week 5 an extra 10° toward extension every week; CKC exercises ROM 0-60°
5-8	Active straight leg raises with increased weight; Leg extension 90-45° without resistance	Gradually increase intensity and weights	Add squat, step up; 3x 15-20 repetitions	
9-19	Add step up and step down; gradually increase intensity and weights of all exercises		Add step down, leg press and squat lunge; 3x 12-15 repetitions	CKC exercises ROM 0-90°; Gradually increase intensity and weights of all ex- 20-25 Change to 3x 6-8 ercises
20-25			Change to 3x 6-8 repetitions with increased load	
26-52	Add squat			

Table 1: Archives of Rehabilitation.

The altered biomechanics in functional performance and leg strength deficiency is known for ACL injury. Negative outcomes is responsible after 2 yrs of ACLR is due to >20% quadriceps strength deficient. Hence, the quadriceps plays vital role in pre-habilitation as well as post rehabilitation ACLR. From the literature you can see in table 1 which is progressive strength ex's in history of ACLR. CKC exercise is effective in improving cell production of new ACL graft. Mini squat and lunges are most effective between 0*-50* flexion, this could not put stress on newly reconstructed graft. [6,7,8]

Shelbourne etthat CKC exercise is beneficial for accelerated rehabilitation process. The most disadvantage of this protocol is time base only. There is no individual variation of protocol. Many literature have conflict of Interest regarding when to start OKC exercise for quadriceps. There are many studies who states that OKC should be start after 4 weeks to prevent graft elongation.

accessible for every physical therapist. Recently, two research groups showed that movement quantity measurements are associated with re injury of an ACL. The isokinetic strength and a hoptests are used for return to sports criteria. An athlete can return to sports if he meets> 90% in all of the test.[4, 7]

Test	Start position	Procedure	Sessions	Recorded variable	Picture
Isometric knee extensor strength	Seated at the end of an examination table and had to hold the side-edges with his hands.[18] The hips were placed at 90° of flexion and the tested knee at 60° of flexion. A belt was placed around the examination table erpendicular to the distal tibia of the test leg	The hand-held dynamometer was placed just above the talo tibial joint line.[18] The subject had to build up his Strength in two seconds and then holds a maximum voluntary contraction for three Seconds.	Two practice sessions, before Three test sessions for each leg. Between practice and test sessions, a one minute rest period. Between each test session, a 30 second rest Period. The non-operated leg was tested before the Operated leg.	The highest value (in kg) of the three test sessions for both legs. The Limb Symmetry Index was calculated as the strength of the operated leg divided by the strength of the non-operated leg multiplied by 100.	
Isometric knee flexor strength	Prone on an examination table with the tested knee at 30° of flexion and holding the side-edges of the table with his hands	The hand-held dynamometer was placed at the posterior part of the leg, two cm above the lateral malleolus.[18] The subject had to build up his strength in 2 seconds and then hold a maximum voluntary contraction for 3 seconds.	Two practice sessions, before three test sessions for each leg. Between practice and Test sessions, a 1 minute rest period. Between each test session, a 30 second rest period. The non-operated leg was tested before the operated leg	Two practice sessions, before 3 test sessions for each leg. Between practice and test sessions, a 1 minute rest period. Between each test session, a 30 second rest period. The non-perated leg was tested before the operated leg.	

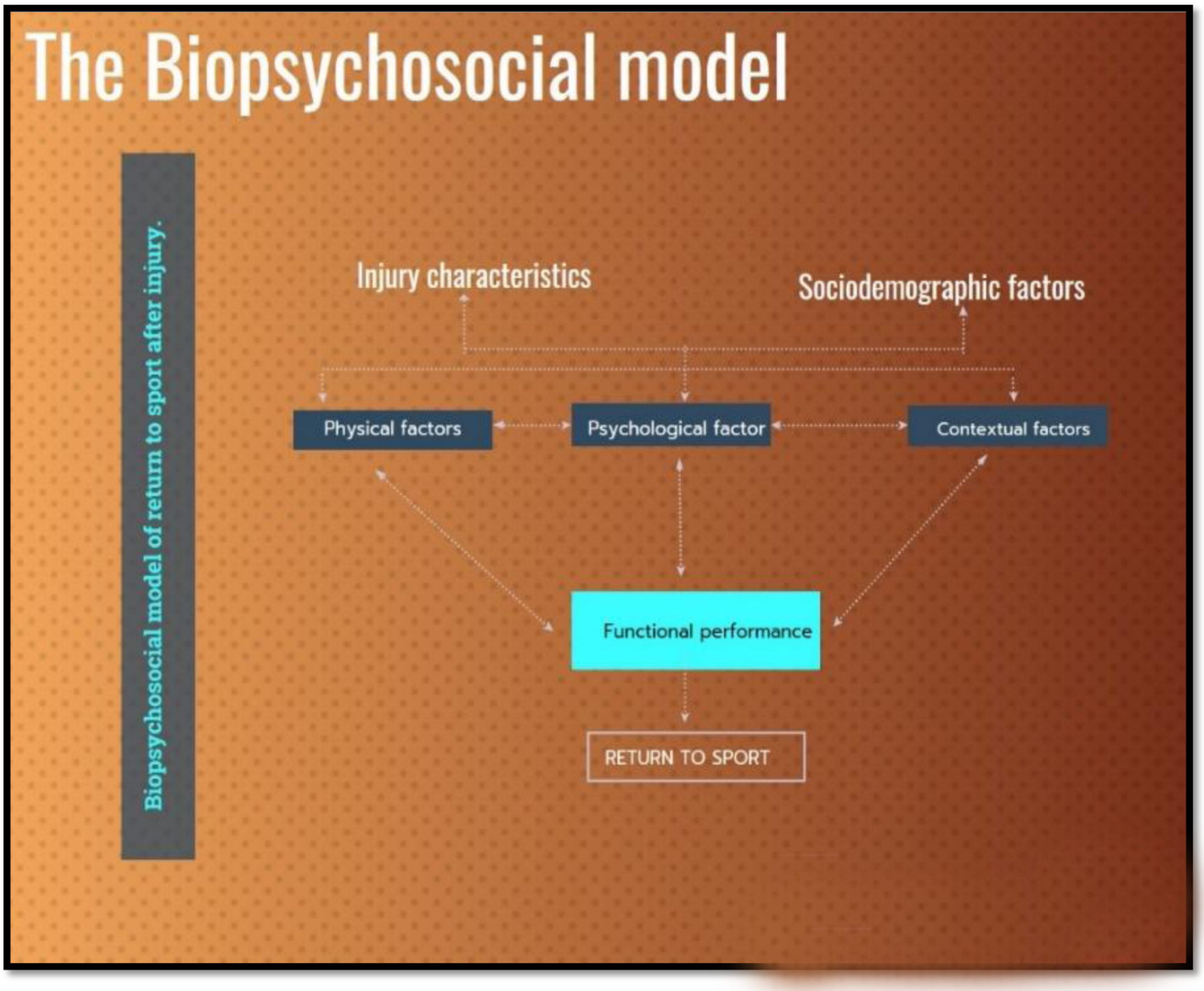


Image 7.1: Biopsychosocial model of return to sport after injury

How to Organize a Return to sports Decision Process?

Each rehabilitation exercise or phase can be considered as a small step in the direction of RTS. Preoperative, operative, and postoperative factors during rehabilitation can affect RTS. This is layer by layer approach within a smooth continuum of recovery throughout the whole rehabilitation programme. It is in line with the contemporary criteria-based rehabilitation approaches, but it is with the traditional 'yes' or 'no' question at the hypothetical 'end' of rehabilitation. There should be consider repeated athletic evaluations during the rehabilitation programme which consider as small steps on the road to RTS. The decision to allow full return to unrestricted athletic activities should not be considered as the endpoint of this continuum [30]. Even though we currently do not know what is exact criteria how RTS criteria develop. Secondary prevention programs have been proposed but their effectiveness for reducing the risk of reinjury and increasing RTS rates have yet to be investigated. A graphical overview of the proposed continuum is presented.

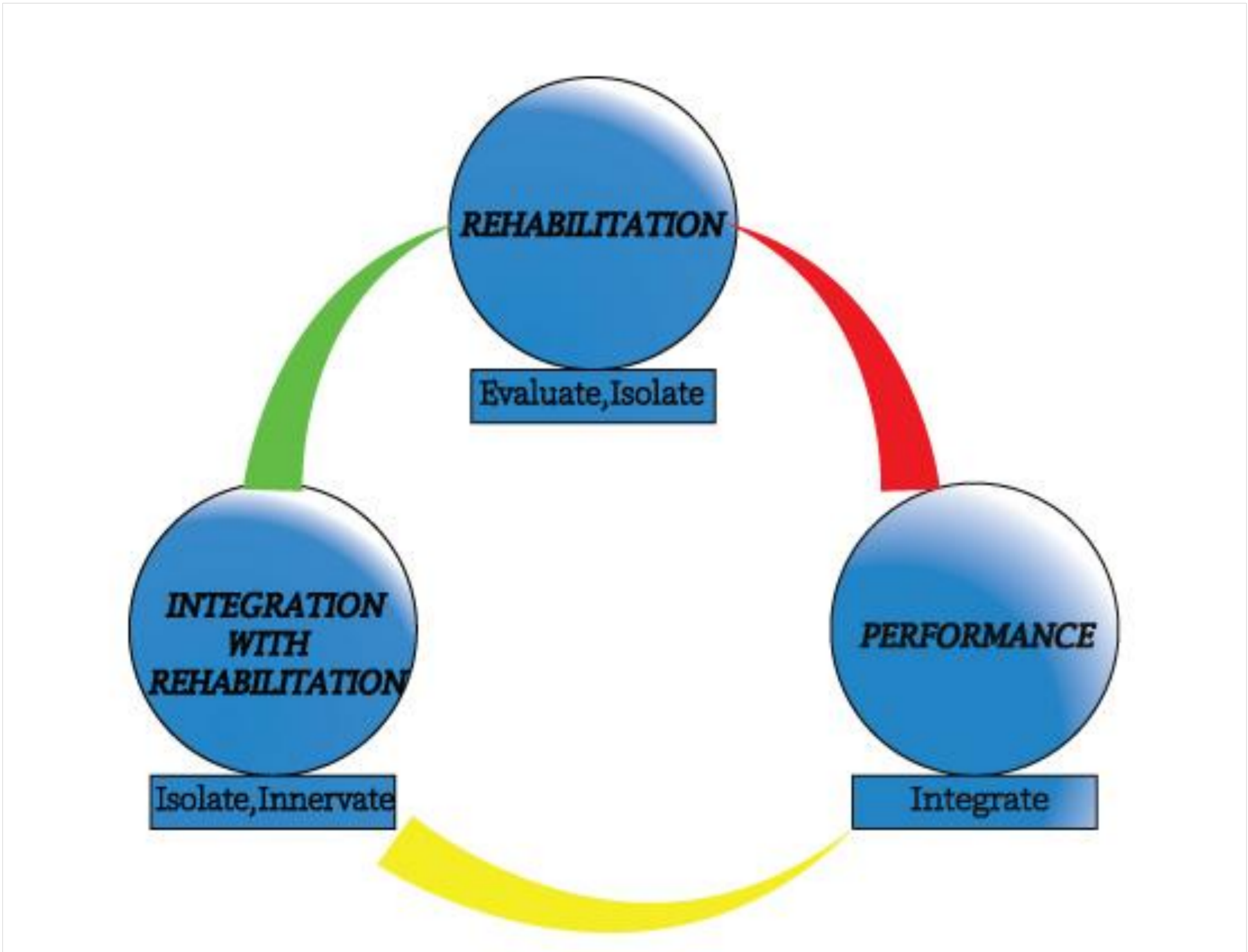


Image 8.2

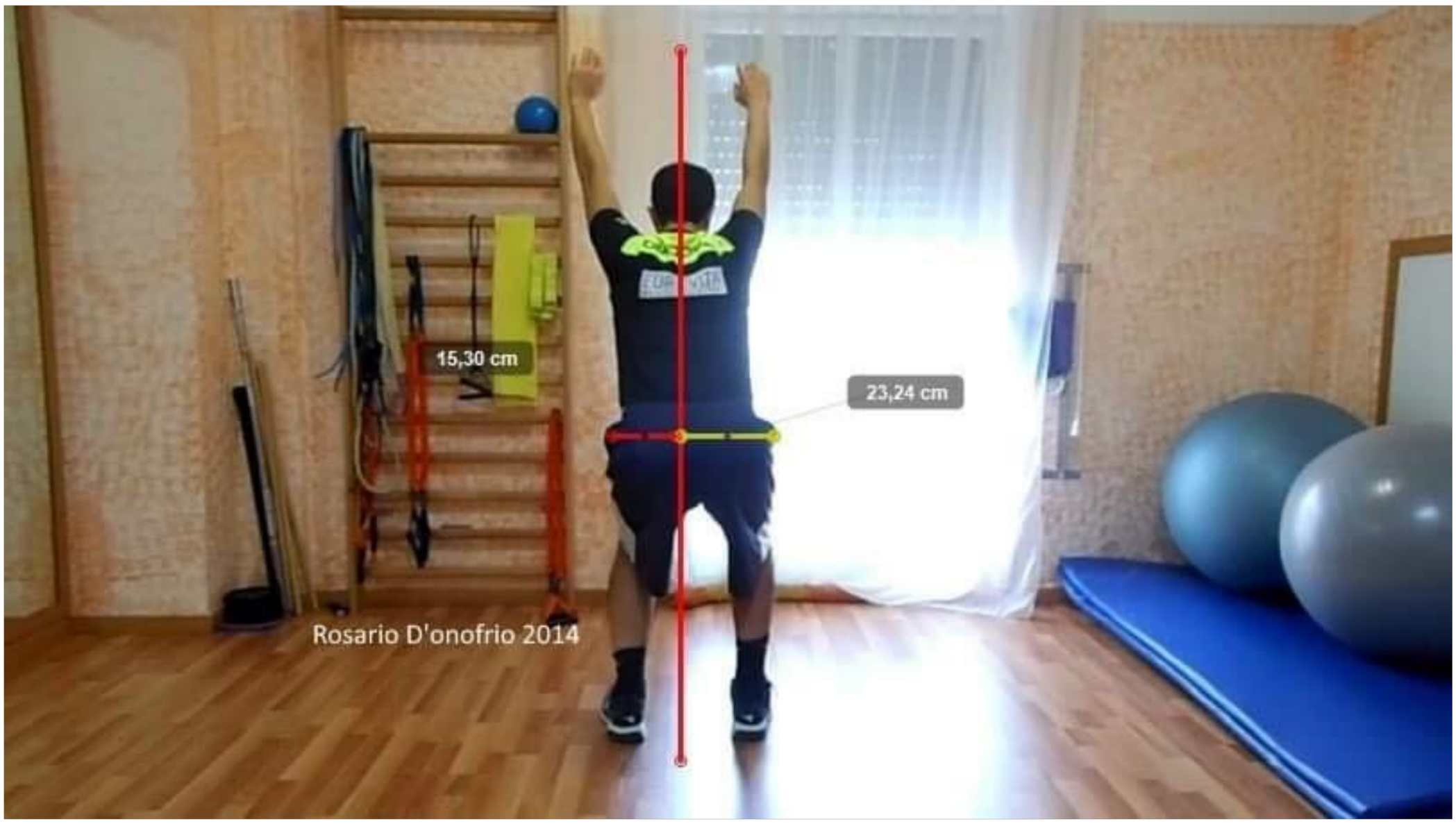
How do we success in jouney of rehabilitation to performance?

It requires the health care professional (including the orthopedics, PT-physical therapist, AT-athletic trainer and SC- strength and conditioning coach.) to understand the performance aspect of training an athlete. The performance specialists, Movement, strength and skill coaches are required for bridging the gap, to understand and respect healing tissue. When these professionals work synergistically in the best interest of the athlete, they will have successfully bridged the gap.

What need to consider during evaluation?

Functional Anatomy Implications

Core training has gained a tremendous amount of attention in the literature over the last several years (1–3). Clinicians with different backgrounds would agree that some element of core strength is required. It is important in injury reduction and sport performance. They realize that injury prevention and optimal



Exercise in a Prevention Program

Plyometrics

Plyometrics focusing on proper technique and body mechanics can help to reduce serious ligamentous injuries, specifically ACL injuries.

Neuromuscular Training

The term neuromuscular training is utilized throughout the literature and is included in most injury prevention programs [42, 62, 55].The objective of neuromuscular training is to improve the ability to generate optimal muscle firing patterns, increase dynamic joint stability, and to perform movement patterns and skills necessary during activities of daily living and sports activities. This may include balance exercises, proprioceptive activities on balance and wobble boards [42,55], single-leg stability activities [44], dynamic joint stability exercises, jump training, plyometric exercises, agility drills, and sport-specific exercises. These types of proprioceptive and balance training can improve postural control and side-to-side imbalances in lower extremity measures.

Strength Training

Strength training incorporate with programme is the most effective at decreasing ACL injury rates; But, strength training alone may not be efficacious for the ACL prevention. There are programs which showed to be effective in decreasing ACL injures without the usage of strength training. Resistance training may help in the reduction of ACL injuries when combined with other training components

1. Starting position

Lie on your stomach and support upper body with your arms. Place your feet vertical to the ground.

6. Bounding:

Starting position: Stand on the take-off leg with the upper body upright. The arm on the take-off leg side should be in front of the body. When viewed from the front, the hip, knee and foot of the take-off leg should be in a straight line.

Action: Spring as high and as far as possible off the take-off leg. Bring the knee of the trailing leg up as high as possible and bend the opposite arm in front of the body when bounding. Land softly on the ball of the foot with a slightly bent knee.

Repetitions: Cover a distance of 30 meters twice.

Bounding Improves jumping power and technique.

Important: When viewed from the front, the hip, knee and foot of the take-off leg should be in a straight line. · Bring the trailing leg and the opposite arm up in the front of the body when bounding. · Land on the ball of the foot and with the knee bent to cushion impact. · Don't let knee buckle inwards during take-off or landing. · Never land with extended knees or on the heels.