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REVIEW

Paediatric Knee Injuries: A Narrative Review

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Abstract

The prevalence of paediatric knee injuries is increasing due to higher participation in competitive sports, larger build and more use of imaging in diagnosis. A thorough history of injury (including mechanism and symptoms of pain and instability), together with a comprehensive examination (presence of an effusion, tender areas, range of movement and joint laxity) will dictate the need for radiological investigations. Magnetic Resonance Imaging (MRI) is indicated in most paediatric patients with a history of injury and an acute knee effusion, which indicates damage to an intra-articular structure. Red flags requiring onward referral to a specialist include diagnosed fractures, traumatic knee effusion, instability, or persistent unexplained nocturnal pain or lump. Correct identification and management of injuries will help reduce long-term morbidity. The aim of this review is to provide the reader with an understanding of the management of paediatric knee injuries at primary presentation in the community setting or emergency department.

Key words: knee injuries; child; adolescent; athletic injuries; paediatric knee injuries

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Introduction

Knee pain is common in the paediatric population, with 12% of 8–13 years old's experiencing the symptom at least once a week (El-Metwally et al, 2006). Paediatric patients (or "children") are defined by the British Society for Children's Orthopaedic Surgery (BSCOS) and the British Association for Surgery of the Knee (BASK) consensus as those aged 18 years or younger (Nicolaou et al, 2021). Injury-related knee pain is also common in this age group with up to 54% reporting some degree of sports-related knee pain at least annually (Yen, 2014). Growth-related knee pain (e.g., Osgood Schlatter's disease) is the most common cause of knee pain without effusion. However, more serious aetiologies (e.g., ligament, meniscus or bone injuries) are usually related to sports injuries, traffic accidents, falls or direct blows. The majority of traumatic knee effusions in paediatric patients (70%) are associated with intra-articular pathology; the most common being anterior cruciate ligament (ACL) injury, fracture or patellar dislocation (Askenberger et al, 2014).

A focused history, thorough examination and appropriate investigations ensure that conditions requiring reassurance and expectant management are distinguished from more serious pathologies requiring urgent or operative intervention. The sequelae of poor management includes growth disturbances, loss of function and early-onset arthritis (Fabricant and Kocher, 2017; MacDonald et al, 2021). This

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may have a significant impact on engagement in educational, social and sporting activities including 'career-ending' disabilities and significant psychological trauma (Toomey et al, 2022).

This paper provides a narrative review to aid non-specialist clinicians in the initial management of this population of patients with knee injuries by providing an evidence-based review of (1) anatomical differences between paediatric and adult knees, (2) common paediatric knee disorders, (3) typical presenting features, (4) examination sequence, (5) appropriate investigations, (6) principles in management, (7) reasons for referral to specialist paediatric knee surgeons and (8) the emerging role of injury prevention.

How do Paediatric Knees Differ from Adult Knees?

The paediatric skeleton differs from that of the adult by the presence of physes (growth plates) and apophyses (attachment points for ligaments and tendons). Most of the bony growth in the leg arises from the knee, where there is a physis in the distal femur and proximal tibia, as well as an apophysis at the insertion of the patellar tendon (Bailey et al, 2020).

Common fracture patterns involving the physes were famously described by Salter and Harris (Salter and Harris, 1963). These carry a risk of growth disturbance. Ligament and tendon attachments to the apophyses can result in avulsion fractures of these structures.

The menisci and ligaments are anatomically and structurally similar to those of the adult but benefit from a richer blood supply which improves their capacity to heal following injury and/or repair. This is not the case for the anterior cruciate ligament, which heals poorly when torn in both paediatric and adult patients (Filbay et al, 2023). Repair (rather than reconstruction) of this structure is confined to the research setting in the UK (Nicolaou et al, 2021).

What Sorts of Injuries Should I be Aware of?

Injuries may be categorized as bony fractures, soft tissue damage, repetitive stress, or patellofemoral in origin (Table 1) (Nicolaou et al, 2021). Detailed descriptions of each individual pathology and treatment modalities for specialists have been well covered elsewhere and are beyond the scope of this review (MacDonald et al, 2021). Any acutely injured knee with a joint swelling, suggests an internal derangement within the capsule of the knee joint that requires further investigation with either careful staged re-examination and/or a Magnetic Resonance Imaging (MRI) scan (Table 2).

Bone Fractures

Intra-articular fractures of the knee are less common than shaft fractures of the femur or tibia, and tend to occur in the distal femoral physis in up to 52% of cases (Basener et al, 2009). The undulating nature of the distal femoral physis predisposes children to growth disturbance (Muhammad et al, 2022). Intra-articular fractures

Table 1. Common Injuries.

Type of injury	Injury
Fractures	Distal femoral physeal fracture Proximal tibia physeal fracture Patella sleeve avulsion Tibial tuberosity fracture Tibial spine (anterior cruciate ligament (ACL) avulsion) fracture
Soft tissue: Be aware of UK Guidelines published by British Society for Children's Orthopaedic Surgery (BSCOS) and the British Association for Surgery of the Knee (BASK) (Nicolaou et al, 2021)	Anterior or posterior cruciate ligament injury Medial and lateral collateral ligament injury Posterolateral corner injury Multiligamenous injuries Meniscal injury Fat pad impingement/inflammation Extra-articular injuries (i.e., traumatic bursitis, ecchymosis, muscular injuries)
Repetitive stress	Osgood-Schlatter's disease Sinding-Larsen-Johansson syndrome Patellar tendonitis (Jumper's knee) Synovial plica Osteochondral injury/defect (osteochondritis dissecans)
Patellofemoral	Maltracking Subluxation or dislocation/medial patellofemoral ligament injury Chondral injury/bone oedema ("chondromalacia patellae")

of the tibia are rarer and usually affect the physis, tibial spine or tibial tubercle with a high rate of associated soft tissue injury (Sanders et al, 2023). Patella fractures are usually sleeve avulsions from the inferior pole (Bailey et al, 2020). Any fracture involving the physis is at risk of growth arrest, especially if the diagnosis or treatment is delayed. This signifies the importance of accurate recognition and treatment with appropriate post-operative follow-up (usually until skeletal maturity) to ensure opportunities for guided growth (in angular deformity), contralateral epiphysiodesis (in leg length discrepancy) or epiphysiolysis (in presence of a bony bar) are instituted when appropriate.

Soft Tissues

Ligament injuries should be suspected in cases of an immediate joint effusion after injury, often sports-related. Although usually an injury of adults, due to the dramatic rise in competitive athletic activity in skeletally immature patients, there has been an increase in the incidence of ligament tears in the younger patient population (MacDonald et al, 2021). Anterior cruciate ligament injuries often occur during landing from jumping, decelerating and cutting maneuvers with subsequent valgus collapse (Schick et al, 2023). Increased injury rates have resulted in a 29-fold increase in paediatric ACL reconstructions in the UK over the last 20 years (Nogaro et al, 2020). Posterior cruciate ligament injuries are rare in children and

may signify either an avulsion of the ligament or an intrasubstance tear (Scarcella et al, 2021). Motor vehicle accidents and sports-related trauma are the most common causes. Medial collateral ligament injuries are common in children who participate in sports and are subjected to valgus stress. Most can be managed nonoperatively but surgery may be required in cases of medial knee instability (Pearce et al, 2023). Isolated lateral collateral injuries are exceptionally rare and usually occur as part of a posterolateral corner injury. This, in turn, may occur as part of a multiligamentous injury (with the ACL also involved) (Kinsella et al, 2020).

Meniscal pathology classically presents with a delayed effusion over several hours or days. The congenital abnormality of discoid lateral meniscus is present in 2–5% of children, which is a shape variant that is prone to tearing (Saavedra et al, 2020). Meniscal pathology in association with ACL injury is common and is an absolute indication for surgical meniscal repair in most cases (Asokan et al, 2023).

Repetitive Stress

Osgood-Schlatter's and Sinding-Larsen-Johansson syndromes are examples of traction apophysitis of the distal and proximal patellar tendon respectively, and present as anterior knee pain. Suspicion should be raised in children aged 8–14 years who play sports that involve jumping or kneeling. 'Jumper's knee', or patellar tendonitis, is another common presentation.

Osteochondral injury or defect (formerly known as osteochondritis dissecans) represent injury to the articular cartilage and subchondral bone of the knee joint. The aetiology remains debated but is likely to include repetitive microtrauma, subchondral insufficiency fractures or ischaemia (Laor et al, 2012). Presentation can range from completely asymptomatic (indicating a stable lesion) to effusions (unstable lesions) and mechanical symptoms of locking or giving way (loose body).

Patellofemoral

Patella dislocations may be idiopathic or secondary to trauma. In a traumatic dislocation, the patella moves laterally and there is obvious deformity to the knee. There is often an effusion on reduction, indicating either an osteochondral fracture or a tear of the medial patello-femoral ligament. Recurrent dislocations are common and should be referred to an orthopaedic surgeon who can assess for predisposing anatomical factors and arrange appropriate treatment, that may include physiotherapy or in some cases surgical stabilization.

Differential Diagnosis and Red Flags

Atraumatic causes of a painful or swollen knee include inflammatory arthritis, infection, metabolic bone disorders, and tumour. Those with night pain, fever, weight loss, fatigue, weakness, intense pain or lumps need urgent orthopaedic assessment.

How do Patients Present?

A thorough history should be taken to determine mechanism of injury. Direct trauma usually results in fractures whilst twisting will result in apophyseal

avulsions, ligament tears or meniscal pathology. The most common mechanism of ACL injury is a non-contact twisting injury with the foot planted on the ground. Non-accidental injury should always be considered and appropriate safeguarding pathways should be followed in cases of unexplained injury. Paediatric and orthopaedic input can help determine if the mechanism fits the injury pattern.

Common findings following knee injury include pain, swelling, decreased range of movement and mechanical symptoms (Fig. 1). Note that diffuse knee pain is non-specific whilst highly localised pain usually indicates structural pathology (Fig. 2).

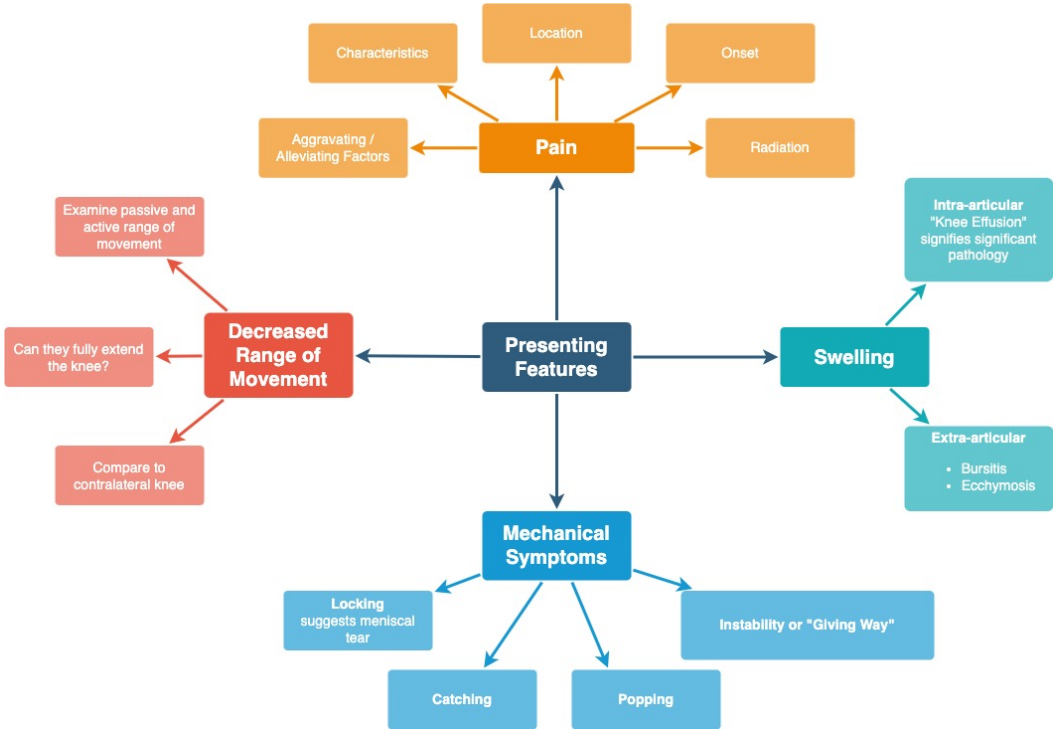

Fig. 1. Presenting features.

How Should I Examine the Young Knee?

A systematic approach with a look, feel, move and specific test algorithm is warranted (Fig. 3).

Look: The child is appropriately undressed in the presence of a chaperone and parent. The initial assessment includes a gait analysis if the child is able to bear weight. Symmetry and muscle girth difference can be measured from fixed points (i.e., 10 cm proximal to the tibial tubercle). Significant muscle girth difference signifies chronic disuse atrophy secondary to limb neglect due to pain. Old scars can also be seen and commented on.

Feel: It is important to palpate the knee starting away from where the child has pain. It is often helpful to examine the non-injured knee first as this will build trust and confidence in the examiner. Presence of asymmetrical warmth or a knee effusion are important to recognize as these indicate significant pathology. Adopting a

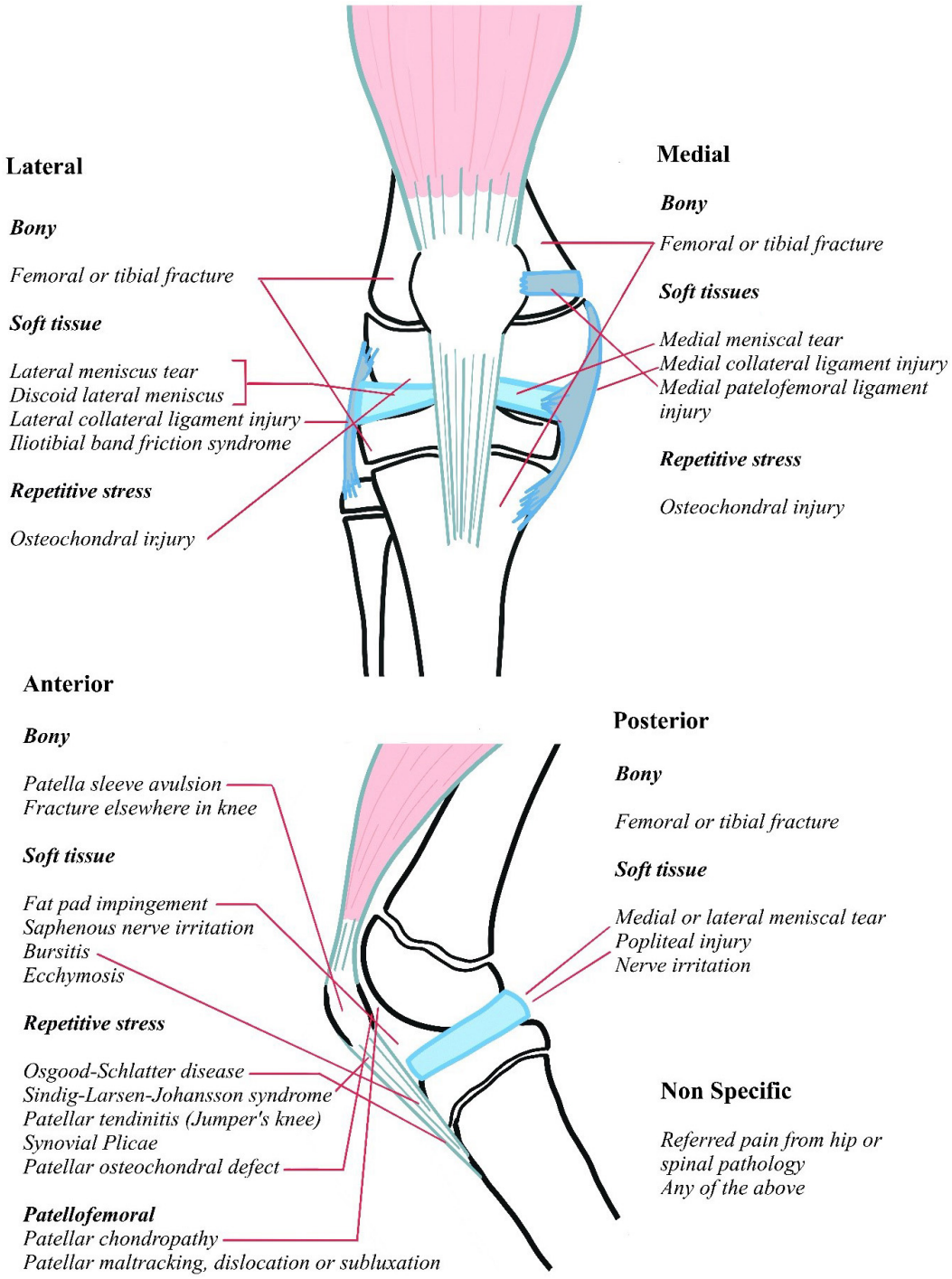

Fig. 2. Location of knee pain and likely structural pathology.

systematic approach to feeling the important structures of the knee will help guide the examiner towards the likely diagnosis (see Fig. 2).

Move: Examine the patellofemoral joint for tracking (looking for a 'J'-sign), patella mobility (noting the number of quadrants of translation and patella tilt) and apprehension at 30 degrees of flexion (the angle at which the patella engages the trochlea). The range of movement of the joint should be recorded including whether hyperextension is present as this may signify genu recurvatum or hyperlaxity.

Special Tests: There are a multitude of examination techniques to determine ligament derangement. It is important to compare these with the uninjured knee. Recognized tests for the ACL include the Lachman test, anterior drawer and the pivot shift maneuver. Posterior cruciate ligament (PCL) testing includes the reverse-Lachman test, quadriceps active test and posterior sag +/– drawer. The medial collateral ligament (MCL) and lateral collateral ligament (LCL) can be examined by performing valgus and varus stress examination at 30 degrees of flexion respectively. Posterolateral corner injuries can be determined with the Dial test. Although a McMurray's test can be performed for meniscal pathology, it is often painful for the child and should only be conducted in select cases if at all.

General Points: Examining the ipsilateral hip joint should be conducted to exclude referred pain. Record a Beighton score for hyperlaxity as this may guide surgical management options in children with pathology amenable to intervention.

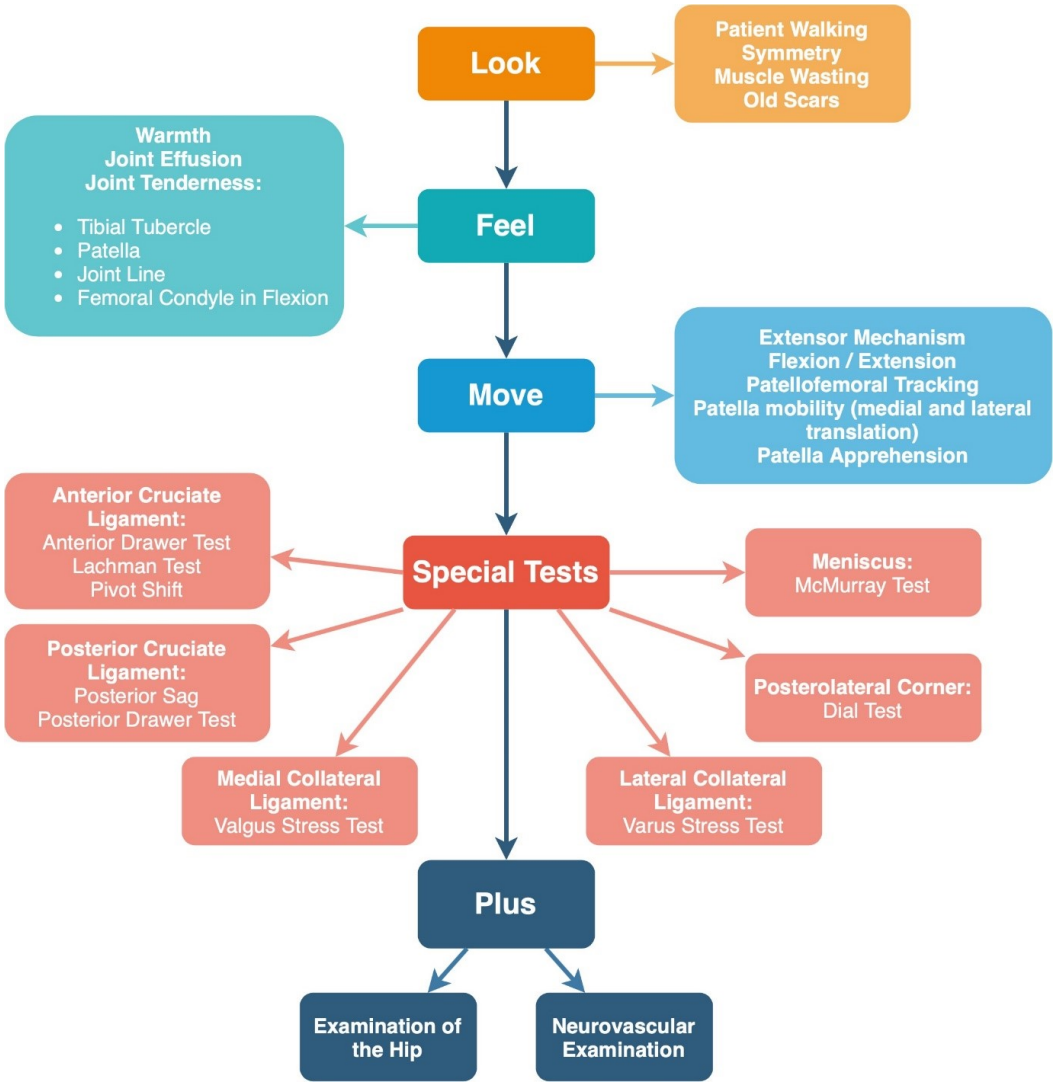

Fig. 3. A systematic approach to examining the injured knee.

Which Investigations are Useful and Why?

Plain radiographs may reveal physeal fractures, loose bodies or traction apophysitis. The Pittsburgh Knee Rule is a useful aid that balances the need for radiographs with excessive radiation exposure (Fig. 4). Clinical acumen should always be relied on more heavily than any 'rule'.

Plain radiographs may be normal in up to 56% of patients with traumatic effusions, as there may be soft tissue pathology, which can only be detected on MRI (Askenberger et al, 2014).

In children with physeal or epiphyseal injuries, a Computed Tomography (CT) scan is often required to help characterize the configuration of the injury and helps to guide surgical fixation. The judicious use of CT in children is recommended and should only be considered if it will significantly aid diagnosis and/or operative planning.

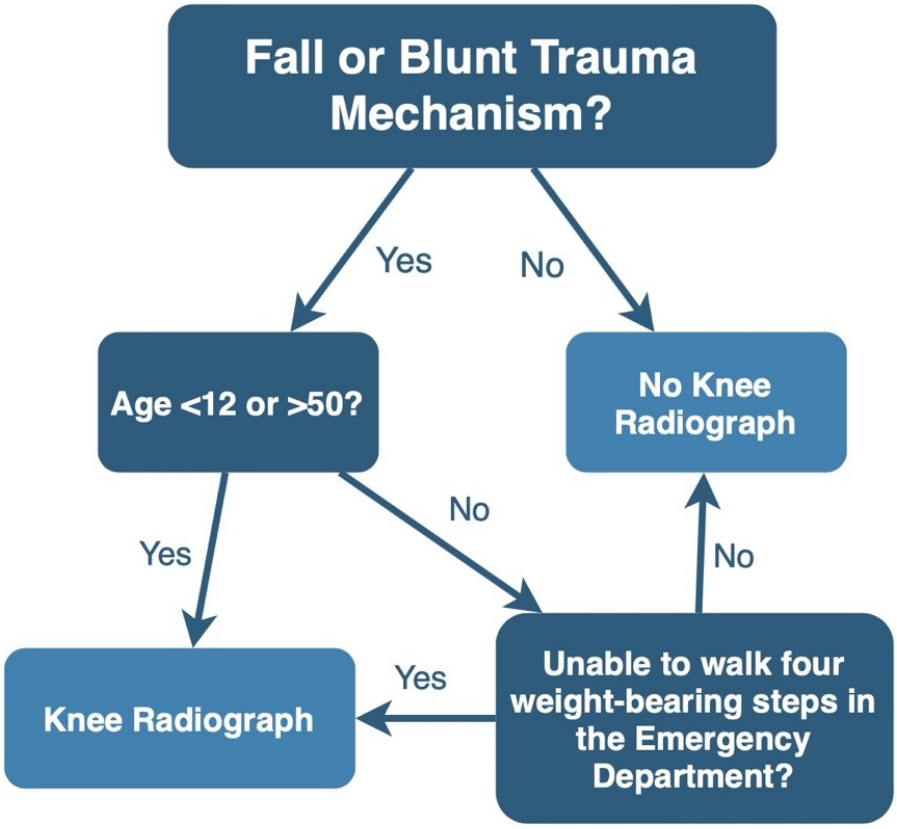

Fig. 4. The Pittsburgh Knee Rule to aid decision making on obtaining knee radiographs.

The British Association for Surgery of the Knee (BASK) and British Society for Children's Orthopaedic Surgery (BSCOS) steering committee on paediatric soft tissue knee pathology report recognizes that clinical examination findings are difficult to interpret and therefore mandate that any acute knee injury with an effusion in a child requires either careful re-examination in a few weeks or further investigation with a MRI scan (Table 2) (Nicolaou et al, 2021).

Table 2. Indications for Magnetic Resonance Imaging (MRI) scanning.

Indications for MRI scanning
Traumatic knee effusion
Mechanical symptoms such as instability or locking
Suspected ligament or meniscal injury
Suspected osteochondral injury
Patella dislocation with effusion or recurrent patella dislocation
Extensor mechanism failure
Recurrent unexplained knee symptoms/suspected tumour

Although useful in evaluating paediatric knee injuries, MRI scans have been shown to be 75–95% sensitive and specific for ACL injuries and hold an even lower accuracy in detecting meniscal pathology in children (Dawkins et al, 2022). Therefore, a 'normal' MRI scan does not exclude knee injuries and specialist paediatric musculoskeletal radiologist review as part of a wider multidisciplinary team approach is mandatory. Close monitoring and reassessment of the patient after an appropriate interval can help determine diagnosis.

Children with confirmed intra-articular pathology that requires intervention should undergo long-leg alignment radiographs and radiographic skeletal age assessment (Nicolaou et al, 2021).

If metabolic bone disorders, unusual fractures, inflammatory arthritis or infection is suspected then blood tests including vitamin D levels, full blood count, auto-antibodies and inflammatory markers may be considered with onward referral to paediatric rheumatology or infectious disease doctors as appropriate.

What are the Principles in Management?

Determine if the knee injury is acute or chronic. Depending on the chronicity, different management strategies can be employed (Fig. 5).

When Should I Refer and How can I Equip My Patient Adequately to Ensure an Efficient Specialist Opinion?

Common reasons for referral are included in Table 3. Whether in the community or emergency department (ED) setting, a referral to the orthopaedic service should include relevant history, examination and imaging findings. In urgent cases, discussion with the on-call orthopaedic team can often help facilitate appropriate same-day or clinic follow-up for the child. In referral letters, be sure to include the report of any imaging that has been conducted and any digital images should be sent via an Image Exchange Portal (IEP) service to the hospital to which the patient is being referred. It is important to recognize that some children may need onward referral from their local orthopaedic hospitals to high-volume units or surgeons if complex pathology is found, thus delays in initial referral should be avoided when possible.

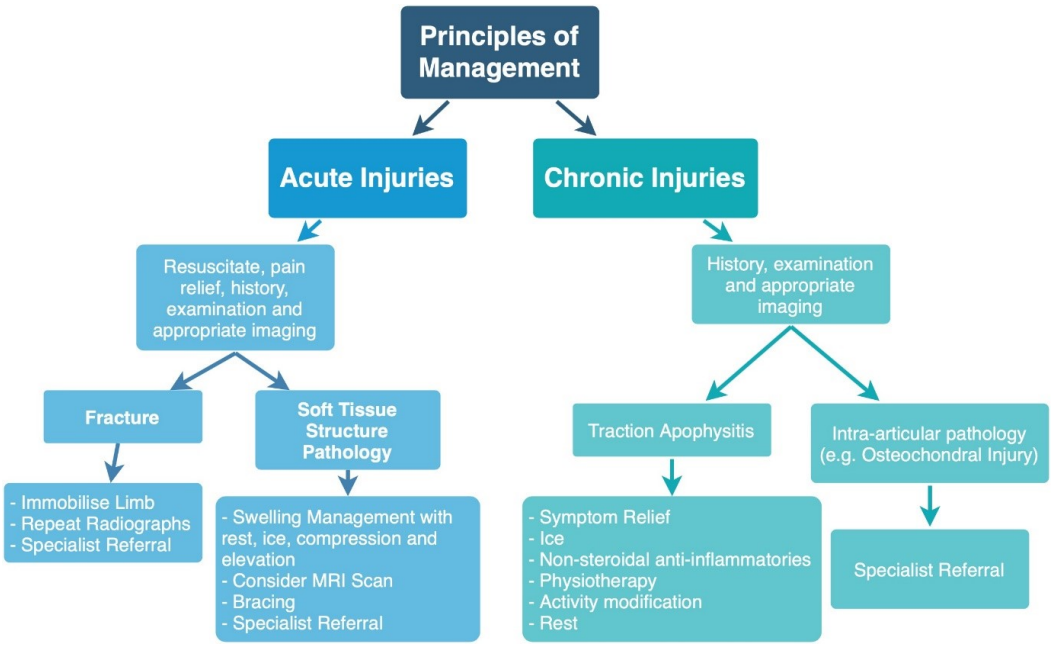

Fig. 5. Principles of managing paediatric knee injuries.

Table 3. Reasons for specialist referral.

Reasons for specialist referral
Traumatic knee effusion (indicating intra-articular structural injury)
Atraumatic knee effusion (referral to paediatric rheumatology unless septic arthritis is considered likely)
Fracture
Patellar dislocation
Ligament injuries
Meniscal tears
Red flag or recurrent unexplained symptoms

What is the Role of Injury Prevention?

There is strong evidence that engagement in injury prevention programmes can reduce the risk of sports-related injury (Huang et al, 2020). Such programmes are focused on plyometric, strengthening, agility exercises and feedback on proper landing techniques. Engagement in biomechanical assessments is crucial considering children will differ in their movement patterns and the dynamic stresses they apply to their knees. Clinician engagement with parents, coaches, teachers, and healthcare commissioners to fund and support such programmes is crucial.

Conclusion

Paediatric knee injuries are common conditions that may result in significant sequalae if unrecognized or mismanaged. The anatomy of paediatric knees differs from that of the adult knee with special consideration of the physis, apophysis and growth potential. Injuries can be considered as those that involve the bone

(fractures), soft tissue, repetitive stress or patellofemoral region. It is important to complete a systematic and thorough history (including presenting features such as pain, swelling, mechanical symptoms or decreased range of movement), examination (in a 'Look', 'Feel', 'Move', 'Special Tests', 'Plus' manner), and imaging (which may include radiographs, CT scans, MRI scans, mechanical axis and bone age calculations) if appropriate. Multiple reasons for onward referral exist and red flag symptoms or signs should lead to prompt specialist referral. Injury prevention programmes hold the potential of reducing knee pathology in paediatric patients.

Key Points

- Paediatric knee injuries are common and require a thorough assessment with appropriate initial history, examination and investigations before onward referral to specialists.
- The sequalae of missed or inappropriately treated injuries may result in long term morbidity including growth disturbance and/or deformity, early arthrosis, 'career ending' disabilities, loss of function and psychological trauma.
- Developing appropriate decision-making skills will help the reader avoid the above mentioned issues.
- Encouraging participation in injury prevention programmes is an evidenced based approach for reducing paediatric knee sports trauma.

Availability of Data and Materials

All data of this study are included in this article.

Author Contributions

AMK and CMG made substantial contributions to the conception and design of this research. AMK drafted the original manuscript. Both authors contributed to important editorial changes of important content in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors and contributor declare no conflict of interest.

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