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An Orthopedic Approach to a Child with a Limp: A Step-by-Step Review Article

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Abstract

This article explains the orthopedic approach to limping in children. This is a review article including a selected collection of new articles extracted from PubMed and Google Scholar searched for clinical points and beneficial approaches to limping children. In this paper, limping is divided into two categories, painful and painless. After stating the important points in the patient's medical history and explaining specific examinations in this area, different gait types in children are explained and the best evaluation method for them is presented. Then, paraclinical examinations and imaging are described in a practical evaluation, high-risk etiologies of limping such as infections, tumors, and fractures are explained in detail and red flags are considered at each step. The algorithms and the list of differential diagnoses for each age group are included, which can provide physicians with a more comprehensive approach to limping in children.

Keywords

Limping Child, Abnormal Gait, Claudication Approach

1. Background

Definition: Limping in a child is defined as a child with abnormal walking pattern [1]. It is one the chief complaints in children referred to orthopedics and requires specific attention. Limping may be the sign of a wide range of etiologies from minor disorders to life-threatening causes. Some limping causes like

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Legg-Calvé-Perthes disease, slipped capital femoral epiphysis, developmental dysplasia of the hip, septic arthritis, and malignancies could lead to long-term complications if not diagnosed and treated early [2] [3]. Since many of these etiologies can overlap with other minor diseases, such as transient synovitis and overuse injury, and their clinical signs can resemble each other; thus, diagnosing a child with a limp needs a systematic approach to prevent misdiagnosis [4].

Age levels: Toddlers, children of 1 - 3 years of age, when able to walk independently, usually take wide short steps. Asymmetrical steps with foot slaps, and sometimes falling, are expected in this age group. Children of 3 - 5 years of age usually walk with smoother and more symmetrical steps. Better arm movement and overall coordination of the body are observed in them compared with the younger age group. Finally, by the age of 7, most children walk in a pattern similar to that of their adults, which includes longer and slower strides [3] [4] [5].Therefore, it is important to consider the age of the child in order to differentiate normal variations from gait abnormalities [5].

Categories: Antalgic and non-antalgic gait are the two main categories of limping. Pain in the spine, hip, knee, or ankle induces a shortened stance phase on the affected side for the weight-bearing situation which is seen in antalgic limping. Non-antalgic limping includes excessive flexion of the hip or knee joint during swing phase of the gait resulting in toe walking which may be a sign of other etiologies such as clubfoot, limb length difference, or even neurological disabilities such as cerebral palsy [6] [7] [8].The differential diagnoses for limping are provided in **Table 1** based on age and pain.

Table 1. Most common limping causes in children in each age group.

Age	Pain	Probable Diagnosis
Toddler (<3 years)	+	Toddler fracture, Foreign objects, Septic arthritis, Reactive arthritis, Transient synovitis, Osteomyelitis, Neuroblastoma.
	–	DDH, Limb deficiency, Demyelinating neuropathy, Cerebral palsy, Muscular dystrophy, Spina bifida, Clubfoot, Arthrogryposis, Coxa vara, Hindfoot deformities.
Child (3 - 10 years)	+	Legg-Calvé-Perthes disease, Stress fractures, Kohler disease, Osgood-Schlatter disease, Transient synovitis, Osteomyelitis, Sever disease, Appendicitis, Psoas abscess, Reactive arthritis.
	–	Osteochondrosis, Neuromuscular disorders, Leg-length discrepancy, Lyme disease, Charcot-Marie-Tooth disease, Equinus contracture, Idiopathic tight Achilles tendon.
Adolescent (>10 years)	+	Slipped capital femoral epiphysis, Juvenile idiopathic arthritis, Overuse injury, Stress fractures, Osteochondritis dissecans, Legg-Calvé-Perthes disease, Reactive arthritis, Diskitis, Accessory navicular, Discoid meniscus, Chondromalacia patellae.
	–	Tumors, Malignancies, Tarsal coalition, Ankylosis of the knee joint.

2. History

Obtaining exact history helps the doctor shorten a long list of possible diagnoses. First, whether the limping is painful or not? Then, whether the child can bear the weight? Any history of acute trauma is prone to the diagnoses of fractures, intra-articular injury, strain, and sprains. Gradual worsening of the symptoms without a history of trauma, in the presence of fever or chills, indicates infection and inflammatory process, and without fever or chills is suspicious to stress fractures [9] [10] [11] [12] [13].

History of recent viral or bacterial infection must also be considered. Recent occurrence of conditions such as rash or diarrhea may be indicative of reactive arthritis. Preceding history of pharyngitis could indicate transient synovitis, acute rheumatic fever or migratory polyarthralgia as probable causes of limping. History of insect bites or travelling to rural areas indicates the possibility of Lyme disease [10] [11].

An obvious fracture without a history of trauma indicates the possibility of a pathological fracture or child abuse. Children that are susceptible to abuse must be examined separately from their parents [12] [13].

Questions about the type of pain can also be helpful. Burning pain is more common in nerve involvement, whereas constant pain is more prevalent in infections and malignancies. Moreover, the presence of focal pain strengthens the probability of fractures, infections, and malignancies. Morning stiffness and pain relief with activity guides the physician toward rheumatologic disorder. Pain worsening with activity or any recent physical activity indicates overuse injury and stress fractures [14] [15].

Persistent limb pain is suggestive of interosseous disorders affecting the fibrous tissue between the tibia and fibula, such as a tumor or infection. Recent significant weight loss, anorexia, night sweats and night pain can be associated with malignant etiologies. Serious etiologies usually are more accompanied by night pain instead of pain after physical activity [16].

A detailed history of birth and development, past medical history, immunization status and family history of rheumatological, metabolic, neuromuscular or immunodeficiency disease can be assessed at history overall. To exemplify, a history of bleeding disorder could be associated with hemarthrosis. Displays of sexual behaviors in children or being sexually active should be considered for gonococcal arthritis and reactive arthritis. Limping associated with neck pain, photophobia, or fever that ends in neck stiffness in the clinical exam is a strong indicator of meningitis [12]. **Table 2** shows the important points of inquiry into patients' medical history considering the red flags.

3. Clinical Exam: Physiologic or Pathologic Gait

Do not forget to undress the child completely during the examination. It is important to pay attention to the child's upper body posture and evaluate for scoliosis, kyphosis, and lordosis abnormalities. Sitting position is recommended for spondylodiscitis assessment [14]. The presence of tenderness in the spinal muscles

Table 2. Limping child checklist.

First questions	Red flags
1) Age? 2) Is limping painful or not? 3) Is it worsening or getting improved? Did it relapse? 4) How long did the limping last?	
Trauma History	
1) Any acute trauma? 2) Was there a delay between the trauma and the limping and pain? 3) Can the limb bear weight?	**1**) Persistent limping > 7 days. **2**) Repeated presentations. **3**) Acute onset severe localized arthralgia. **4**) Unable to bear weight. **5**) Sepsis. **6**) Obvious red/swollen joint. **7**) No response to analgesics. **8**) Significantly reduced ROM. **9**) Constitutional symptoms (lethargy, significant weight loss, and reduced appetite). **10**) Nocturnal symptoms (night sweats and night pain).
Infection evaluation	
1) History of viral infections or fever and chill. 2) History of insect bite and travelling to rural areas. 3) Recent pharyngitis, rash, or diarrhea.	
Quality of pain	
1) Radiating or burning pain? 2) Morning stiffness? 3) Persistent or intermittent pain? 4) Association with activity? 5) Time of day of the worsening of the pain? 6) Response to analgesic or not?	
Complementary questions	
1) History of birth and development. 2) Past medical history and vaccination (bleeding disorder, medicine, …). 3) Family history. 4) Sexual activity.	

and the spinous processes on palpation of the child's back is suggestive of causes related to spinal issues, such as trauma, discitis, vertebral osteomyelitis, or spinal cord tumors, all of which can be confirmed by a positive history of back pain [17] [18].

Gait observation in a free space could be vastly enlightening. Monitoring a child when he/she is not paying attention can give the doctor information about the possibility of malingering. Any deviation from the normal state is considered limping. Signs of limping may be found in lumpy, asymmetrical, laborious, or irregular gait, which can be painful or painless. It is necessary to determine whether the child prefers one foot or moves asymmetrically [19] [20].Moreover, considering varus and valgus deformities can narrow the differential diagnosis [21].

As previously mentioned, it is necessary to have a correct understanding of normal gait based on the age of the child to identify deviations from the normal state at the onset of physical examination. Gait is usually immature before 18 months. At this age, the legs are extended to support the body which is called

"toddler's gait" characterized by a wide-based stance and short, unsteady steps. Although the movements of the joints are similar, the knees and ankles are more flexed, and the child cannot maintain the position of the single leg for a long time. The amplitude of the knee flexion decreases during the swing phase and the steps are short, the rhythm of walking is faster, but the overall velocity is slower. The more mature the gait is, the slower the cadence is and the longer the strides are. This developmental change is for a higher energy efficiency and more stable walking [22].

Painful Limping: To examine an antalgic gait, first, we should be alert that some children are unable to express pain and, in some cases, just a reduction in standing time on the disabled side, a decrease in weight-bearing time, or a shortening in the stride length of the opposite limb are signs of antalgic gait. In addition, we should take into consideration that sometimes the painful zone is not the same as the provoking area, like knee pain which could be caused by hip disorders [14] [23].

Protected, slow, and shuffling gait (having difficulty lifting the feet off the ground) is observed in antalgia originating from spinal pathologies. Touch the whole limb and pay attention to the baby's face for grimacing. Prominent distress or disturbance, inability or refusal to bear weight on the affected limb, inconsolable pain, and fixing the limb position for comfort are some warning signs of potentially more serious problems such as compartment syndrome or musculoskeletal sepsis [24].

It is best to start with the evaluation of the painless limb, and then, move on to the painful limb. In this way, we can compare the intensity of the child's reaction. If the child can bear weight on the limping limb, subsequently, both limbs should be carefully evaluated. For toddlers, it is recommended that this evaluation be performed slowly and gently on the lap of the parents [25].

Skin findings, including erythema, ecchymosis, swelling, laceration, and tenderness in the upper and lower anterior iliac spine during the pelvic examination, may indicate avulsion fractures of the anterior superior iliac spine due to the contraction of the sartorius and tensor fasciae lata muscles [26] [27]. racture of the direct head of the rectus has similar manifestations. Mutual symmetry should be considered when assessing the range of motion in the pelvis, knees, and ankles. Evidence of masses and effusions, or maximal tenderness points during the palpation of joints and muscles, could be aroused from the infectious causes or fractures [12] [28].

Internal Rotation of the hip in a simulated prone position is a beneficial test for younger children. In this examination, the child is placed in the parent's arms on his/her chest and the hips are fully stretched to increase the joint pressure by reducing the volume of the joint capsule [3].This position allows a more accurate measurement of the internal rotation of the pelvis compared to the prone and internal rotation position, as the pelvis is stabilized in this position [29]. For babies of older age range, it could be performed in a lying down prone position. Lack of internal rotation of the hip is a sensitive indicator of in-

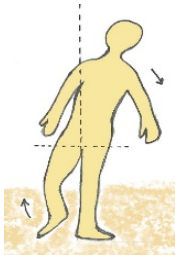
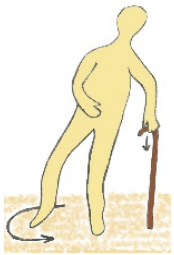
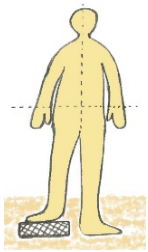
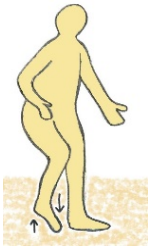
tra-articular etiologies such as Legg disease in 4 - 10 years old and Slipped Capital Femoral Epiphysis (SCFE) in older ages, and some subacute disorders also should be considered such as synovitis and arthritis [4] [24].

Patrick's Test is performed while the child is lying on his/her back with the examiner flexing, abducting, and rotating the hip externally, and examining the sacroiliac joint for any pathology. **Pelvic compression test** is also used for similar cases. The child lies on his/her back and the examiner presses the iliac wings together. Pain in this maneuver again indicates sacroiliac joint pathology [1].

The **crawl test** can be used to localize pathology in children who do not stand on their feet. The child should be encouraged to crawl with the help of the parents. If cross-crawling is done, the pathology is probably in the distal knee [26]. Pelvic osteomyelitis and pelvic and knee sepsis disable a child from crawling. Therefore, physical examination and subsequent imaging studies should be limited to the legs and feet in the presence of a normal crawl test. Possible pathologies in this area include distal tibial osteomyelitis, tibial fracture, osteochondritis of the foot (like Kohler's disease), foot fracture, and the presence of a foreign body in the foot [30].

Non-painful Limping: In non-painful limping, considering the type of abnormal gait could be enormously helpful. **Steppage gait** is when the hip and knee joints are flexed more than normal during the swing phase and toes clear the ground, which is experienced in neurologic conditions that make the child unable to dorsiflex the foot. **Trendelenburg gait** is another type of abnormal gait in which the pelvis is unable to remain in the neutral position, exhibiting a downward tilt toward the normal side during the swing phase. A positive Trendelenburg test signifies developmental dysplasia of the hip (DDH) or any other disorder in hip abductor mechanism [31]. **Circumduction gait** is when excessive extension is seen in the knee and it locks at the end of the stance phase. The affected limb is circumducted or abducted during the swing phase and clears the ground with the toe due to difficulty lifting the foot off the ground. This finding is common in neurologic or mechanical disorders which lead to stiffness of the knee or ankle. We should also consider limb-length discrepancy in this pattern. The Galeazzi test could be employed for this purpose, explained in the tests section. Note that **Short-limb gait** is also seen in milder degrees of discrepancy in which the child equalizes the length of the limbs through knee flexion in the longer limb without plantar flexion or with plantar flexion in the shorter limb and standing on the toes. **Hand-to-thigh gait** can be found in children suffering from quadriceps paralysis due to spinal cord injury, neuro-muscular dystrophy, or polio. This gait is easy to discover; the child pushes the thigh backward manually to stabilize the knee [19]. The last gait type in the non-antalgic group is the **equinus gait** which is typical in congenital talipes equinovarus (CTEV), cerebral palsy, idiopathic tight Achilles tendon, and limb-length discrepancy. In equinus gait, the child walks on the toes painlessly; however, sometimes, it can be the result of calcaneal fracture or a foreign body in the foot as antalgic etiologies [32] [33] [34]. More explanations are provided in **Table 3**.

Table 3. Abnormal gaits.

Abnormal Gait	Definition	Affected area	Image
Steppage gait	Excessive flexion of hip and knee joints during the swing phase with toes clearing the ground	Weakness of dorsiflexor muscles of the ankle	
Trendelenburg gait	Abnormal pelvis exhibiting a downward tilt toward the unaffected side during the swing phase	Weakness of hip abductor muscles	
Circumduction gait	Excessive extension in the knee and locking at the end of the stance phase	Lack of knee flexion or length discrepancy	
Short-limb gait	Flexed knee in the longer limb or dorsiflexed foot in the shorter limb equalizing the limbs	Length discrepancy	
Hand-to-thigh gait	Pushing the thigh backward manually to stabilize the knee	Weakness of quadriceps and fixed knee flexion	
Equinus gait	Walking on the toes painlessly	Weakness of the ankle dorsiflexors, Achilles tendon tightness	

Evaluation of **hip abduction** is performed in the supine position with flexed hips and knees while the soles of the feet are together. Any limitation in this area is in the interest of DDH. The **Galeazzi test**, also known as the Allis sign, is used to check the difference in length between the two lower limbs, with the child lying down and the knees bent so that the soles of the feet touch the ground and the ankles touch the buttocks. The test is positive when the knees are not level [35] Any range of motion limitation or length difference detected may be an indication of DDH, Legg-Calvé-Perthes disease, proximal femoral focal deficiency (PFFD), focal hypertrophy, etc [12] [34] [36] [37] [38].

To evaluate neuromuscular causes of limping, a complete neuromuscular examination is needed. Presence of spastic muscles in the affected limb may be suggestive of upper motor neuron (UMN) lesions such as cerebral palsy; however, hypotonia is suggestive of lower motor neuron (LMN) disorders, including polio and spina bifida. Findings such as muscle atrophy and muscle twitching (fasciculations) may have LMN causes. Additionally, reflexes and tone are decreased, Babinski sign is down, and flaccid paralysis can be detected In LMN disorders. Other subgroups of LMN include hereditary motor and sensory neuropathies (Charcot-Marie-Tooth disease) and myopathies such as Duchenne muscular dystrophy (DMD) [28] [39].

The examination can provide some other clues for non-orthopedic etiologies. For instance, the presence of any skin rash can indicate Lyme disease, reactive arthritis, or viral causes. Abdominal pain or tenderness along with limping is common in appendicitis and psoas abscess. Finding an abdominal mass is expected in neuroblastoma. **Psoas sign** can be used to check these causes. In this test, the child lies on the side and the examiner extends the hip passively. If the child has pain during the hip extension, the test is positive [4] [23]. The list of related tests is provided in **Table 4**.

4. Para-Clinical

Laboratory tests. The performance of paraclinical tests should be based on history and examination. In this way, the cause of limping can be investigated as precisely as possible. If malignancy, infection, or inflammatory arthritis is

Table 4. Clinical exam tests.

Susceptible area	Test
Hip	Hip internal rotation Hip abduction
Sacroiliac joint	Patrick's test Pelvic compression test
Length discrepancy	Galeazzi test (Allis sign)
Distal knee	Crawl test
Abdomen	Psoas sign

suspected, a blood analysis should be performed, including a complete blood count with differential measurement of erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP). Increased WBCs and platelets are common in infections and inflammatory diseases versus malignancies, which are accompanied by cytopenia. ESR and CRP are high in all of them [40] [41].

In case of septic arthritis, joint fluid aspiration and Gram staining, and culture and cell count are necessary. Based on the Kocher Criteria, a non-weight-bearing condition associated with high temperature (>38.5), Serum ESR > 40 mm/h, and Serum WBC > 12,000 cells/mm^3 are strongly susceptible to the diagnosis of septic arthritis. Turbid synovial fluid, WBC count of more than 50,000 to 100,000 per/mm^3 with PMNs > 75%, is pathognomonic of septic arthritis; however, in transient synovitis, clear yellow synovial fluid is observed with lower WBC count (5000 to 15,000 per/mm^3) and PMNs < 25% [10]. Moreover, using real-time PCR-based method to evaluate acute arthritis and determine its cause can be helpful in Kingella kingae cases [42].

Culturing of body specimens would be differentiating in the diagnosis of septic arthritis. For instance, synovial fluid culture is positive in septic arthritis, but transient synovitis demonstrates a negative result. A positive bone culture from the suspected area confirms osteomyelitis. Blood culture sometimes could help in finding the specific source of the infection [40]. To consider some microorganisms specifically, Neisseria gonorrhoeae in urethral, cervical, pharyngeal, and rectal cultures is specific to gonococcal arthritis. Application of urethral and stool culture in patients with positive history of Neisseria gonorrhoeae could be helpful. Salmonella, Campylobacter, Shigella, and Yersinia in stool cultures and Chlamydia in urethral cultures are important findings in reactive arthritis. A positive Group A hemolytic streptococcus in throat culture is suggestive of acute rheumatic fever. Anti-streptolysin O (ASO) titer elevation is also probable in this disease [40] [43].

To evaluate fewer common etiologies, antinuclear antibody (ANA) test is helpful for the primary assessment of systemic lupus erythematosus (SLE)-inducing arthritis. Checking coagulation profile in known hemophilia cases or positive familial histories may show increased activated partial thromboplastin time (aPTT) which suggests hemorrhagic effusion or hematoma. Lyme titer should be checked for suspected patients with history of travelling to endemic areas of Lyme disease [41]. Leukemia should be regarded as a potential cause in children who have a limp, constitutional symptoms, and an elevated white blood cell count (ranging from 10,000 to 100,000) or Cytopenia [44]. Further detail on paraclinical tests is presented in **Table 5**.

Imaging. Imaging is the most important paraclinical evaluation. Plain radiographs of the localized part of the suspected limb are both sensitive and specific for the diagnosis of prevalent causes [3]; however, if pain is not localized, a more generalized X-ray view could be enlightening through comparative evaluation of the contralateral side [45]. There are some common radiographic views in limping

evaluation imaging. Anteroposterior (AP) and frog-leg lateral pelvis radiographs are helpful in the consideration of fracture, missed DDH, and congenital Coxa vara [21] [43]. These views are not required in patients with normal hip motion with regular crawling. It must be noted that the frog pelvis view should be avoided in suspected acute unstable slipped capital femoral epiphysis since it can exacerbate the slip. Alternatively, a true lateral hip view could be applied [46] [47] [48] [49].

Table 5. Laboratory tests.

Paraclinical test		Susceptible etiology	Result
CBC, ESR, CRP		Infection, Inflammation, and rheumatologic disease	Increased WBC and platelet, elevated ESR and CRP
		Malignancy	Increased WBC OR cytopenia, elevated ESR and CRP
Synovial fluid analysis and culture		Septic arthritis	Turbid appearance, WBC > 50,000 - 100,000, PMNs > 75%, positive culture
		Transient synovitis	Clear yellow appearance, WBC = 5000 - 15,000, PMNs < 25%, negative culture
Cultures	Urethra, Cervix, Rectus, and Pharynges	Gonococcal arthritis	Neisseria gonorrhoeae
	Urine and stool	Reactive arthritis	Chlamydia in U/C, Salmonella, Shigella, Campylobacter and Yersinia in S/C
	Blood	Hematogenous Infection	S. aureus, Haemophilus influenzae
	Bone	Osteomyelitis	S. aureus, Pseudomonas, or other microorganisms
	Throat	Acute rheumatic fever	Hemolytic Streptococci Group A
ASO Titer		Acute rheumatic fever	Increased level of ASO titer
Lyme Titer		Lyme disease	Positive
ANA Test		systemic lupus erythematosus	Positive (1:80 or higher)
Coagulation profile		Hemarthrosis, Known hemophilia	Increased aPTT

In non-localized examination or in young children who are unable to cooperate in presenting history, the entire lower leg view is recommended [45] An AP view of both tibias together is beneficial in evaluating knee-related causes such as genu varus and genu varum, or metaphyseal fractures. The lateral view of each tibia including the knee and entire foot demonstrates any possible lesions or misalignments. The AP view of both feet together should be applied for microfractures or foreign bodies [43].

Ultrasonography (US) is another sensitive imaging method for effusion detection in joints, especially in the hip. When it is not possible to distinguish different fluids via the US, ultrasound-guided aspiration should be performed urgently. For alteration of ultrasound-guided aspiration, the synovial fluid aspiration can be performed under fluoroscopic guidance or even blinded by an expert [47]. The synovial fluid analysis has been previously explained. The US is beneficial for detecting cartilaginous joint fracture, radiolucent foreign bodies (such as splinters, plastic, and glass), soft tissue swelling, and abscessess [48] [49] [50].

When pathology cannot be identified through medical history, physical examination, and radiographic and ultrasound findings, **bone scintigraphy** is an appropriate test for the evaluation of stress fractures, osteomyelitis, tumors, and metastatic lesions in the child. This test has low specificity, but has a high sensitivity [51].

CT scans are less commonly used in the primary investigation steps of limping causes due to the high dose of radiation, nevertheless, the modern CT scan techniques offer much lower radiation dose. Sometimes, a three-dimensional CT scan is performed for a more detailed imaging of bone abnormalities including occult fractures, benign lesions such as simple bone cysts, non-ossifying fibromas, and osteoid osteomas, visualization of the cortical bone, and intra-abdominal causes like neuroblastoma or hepatosplenomegaly [52] [53].

Magnetic resonance imaging (MRI) with high sensitivity and specificity is a great option for the examination of joints, cartilage, medullary bone, muscles, and vascular abnormalities and can be used in the form of localized or whole-body MRI. This imaging method is suitable for confirming osteomyelitis, identifying stress fractures, early diagnosis of Legg disease and avascular necrosis of the femoral head due to sickle cell disease, and determining the extension of malignancies. Initial radiographs are commonly used in acute hematogenous osteomyelitis, but MRI could be helpful in earlier diagnosis and prevention of further sequels. Comparison of the images of two hips is also used to detect pre-slip. Spinal disorders such as discitis are best evaluated through MRI [54] [55]. The application of different types of imaging is presented in **Table 6** and the radiographies of some etiologies are shown in **Figure 1**.

5. Diagnostic Algorithm

Figures 2-4 show the practical algorithms for the diagnosis of the causes of limping in a child.

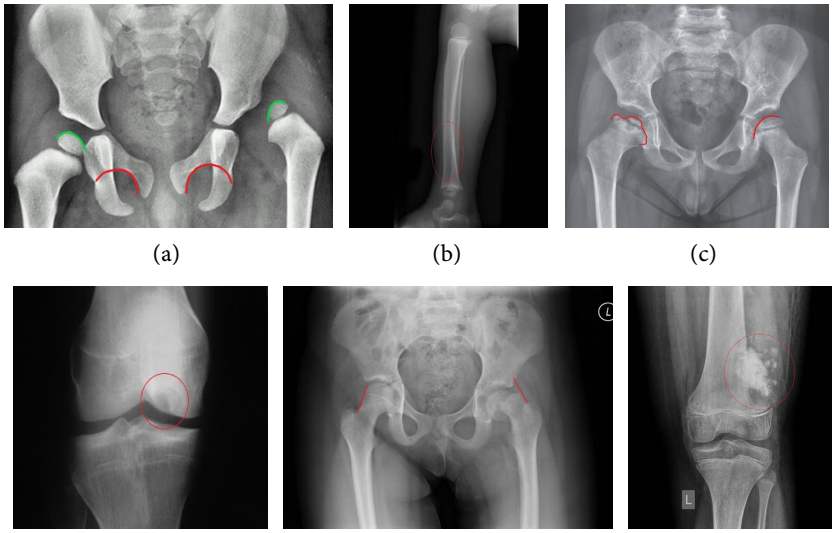


Figure 1. The radiographies of some limping etiologiesin children; (a): Developmental Dysplasia of the Hip (The imbalance of the two green indicators is important for diagnosis), (b): Toddler fracture (The fracture line is circled), (c): Legg-Calvé-Perthes (The flattened femoral head in the right shows the femoral head collapse), (d): Osteochondrosis (The hypodense lesion is circled), (e): Slipped capital femoral epiphysis (The red line in the left shows the displacement of the femoral head), (f): Osteosarcoma (The hyperdense lesion is circled)

Table 6. Imaging and the proper X-ray views for different limping causes.

Imaging	Indications				
Pelvis X-ray	Missed DDH	Any pelvic and hip Fractures	Coxa vara	Slipped capital femoral epiphysis	Legg-Calvé-Perthes disease
Hip X-ray	Femoral neck fracture, Dislocations, Bone lesions, and Degenerative diseases				
Knee X-ray	Malalignment	Knee arthropathy			Osteoarthritis
Tibia fibula X-ray	Foreign body	Osteomyelitis		Bone lesion	Ankle or Knee dislocations
Ankle X-ray	Syndesmotic injury	Bone lesions of the distal lower leg, talus, and proximal fifth metatarsal		Lisfranc injury	Hindfoot deformities
Dorsoplantar foot X-ray	Foot malalignment, Lisfranc injury				
Ultra-sonography	Softs tissue injuries (tendon ruptures, tendonitis, tenosynovitis, bursal pathologies)				
	Abscesses	Evaluation of joint effusion and arthrocentesis			Foreign bodies
Doppler-sonography	Venous stenosis, Emboli				
CT scan	Occult fractures, Bone lesions (bone cysts, non-ossifying fibromas, osteoid osteomas), Intra-abdominal masses				
MRI	Osteomyelitis confirmation	Stress fracture detection		Early diagnosis of leg disease	
	Early avascular necrosis	Evaluating the extension of malignancies			Spinal disorders
Bone Scan	Hidden stress fracture	Osteomyelitis		Tumors	Metastatic lesions

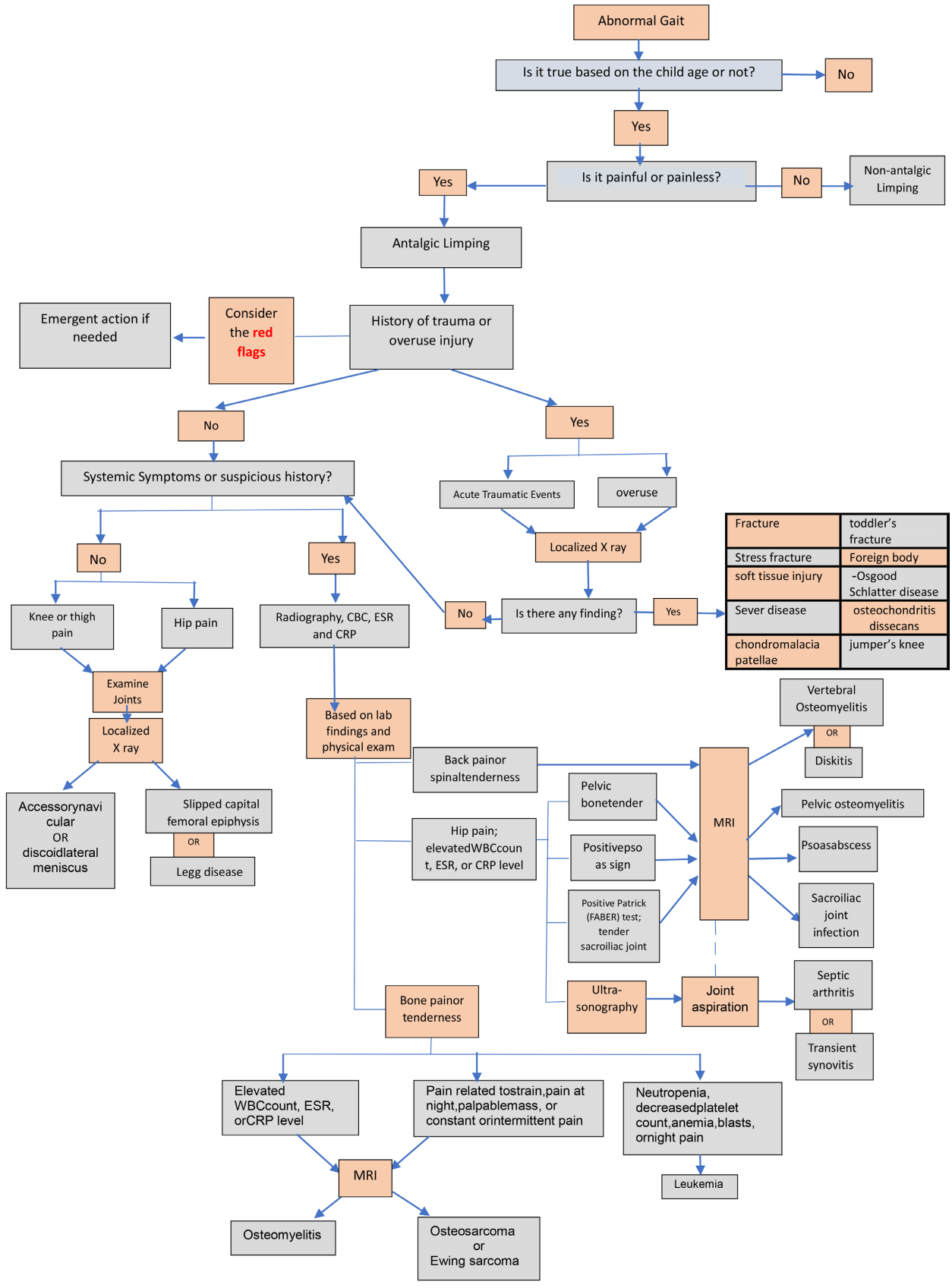


Figure 2. The approach to antalgic gait.

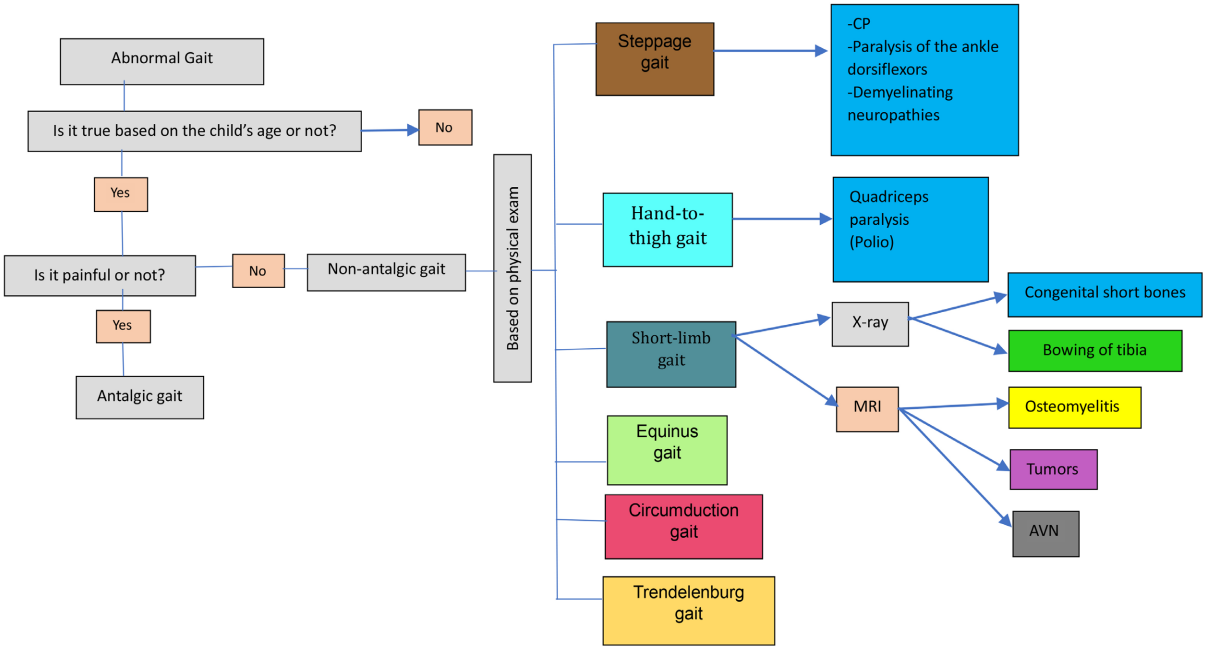
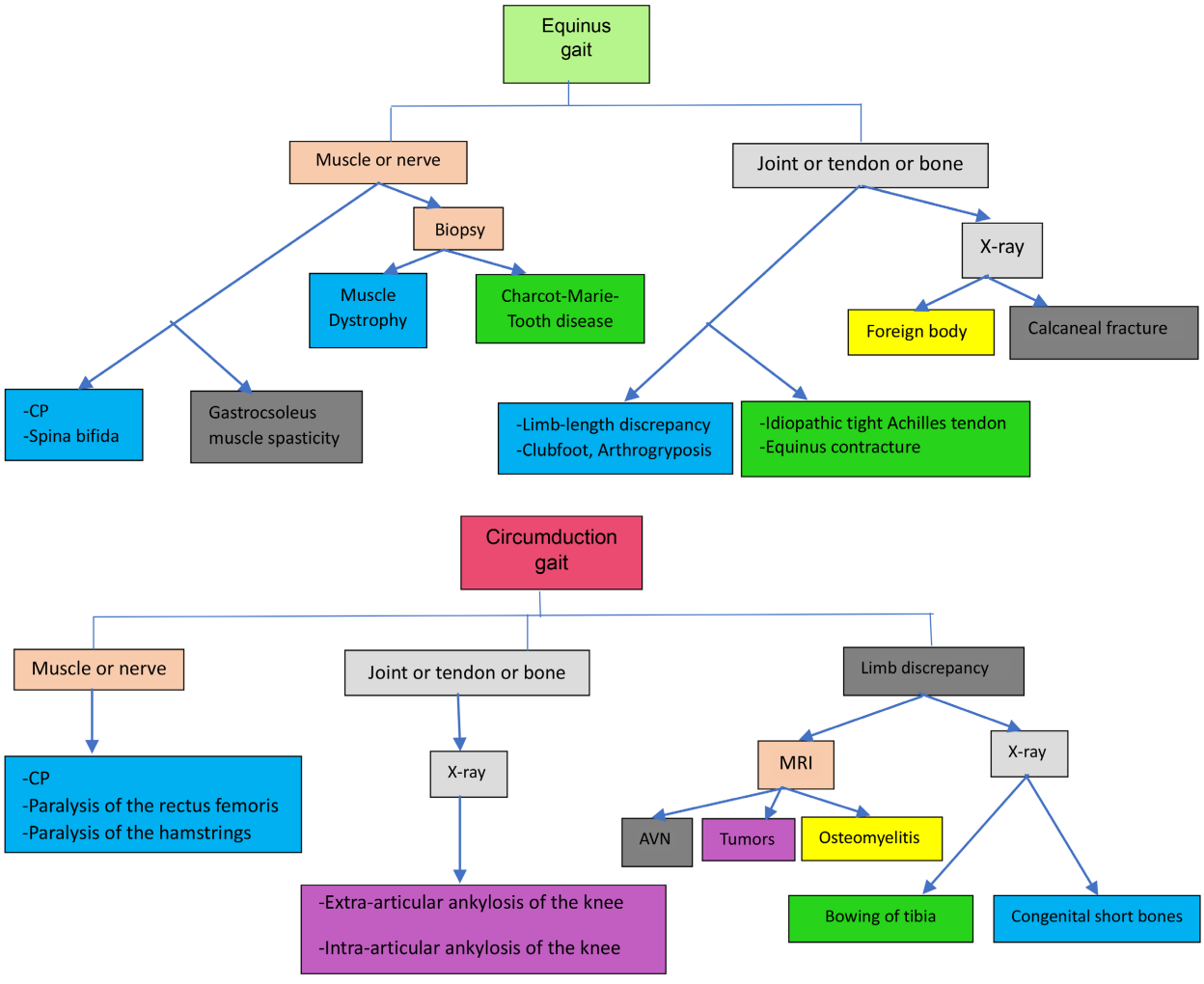


Figure 3. The approach to non-antalgic gait (Steppage gait, Hand-to-thigh gait and Short-limb gait).



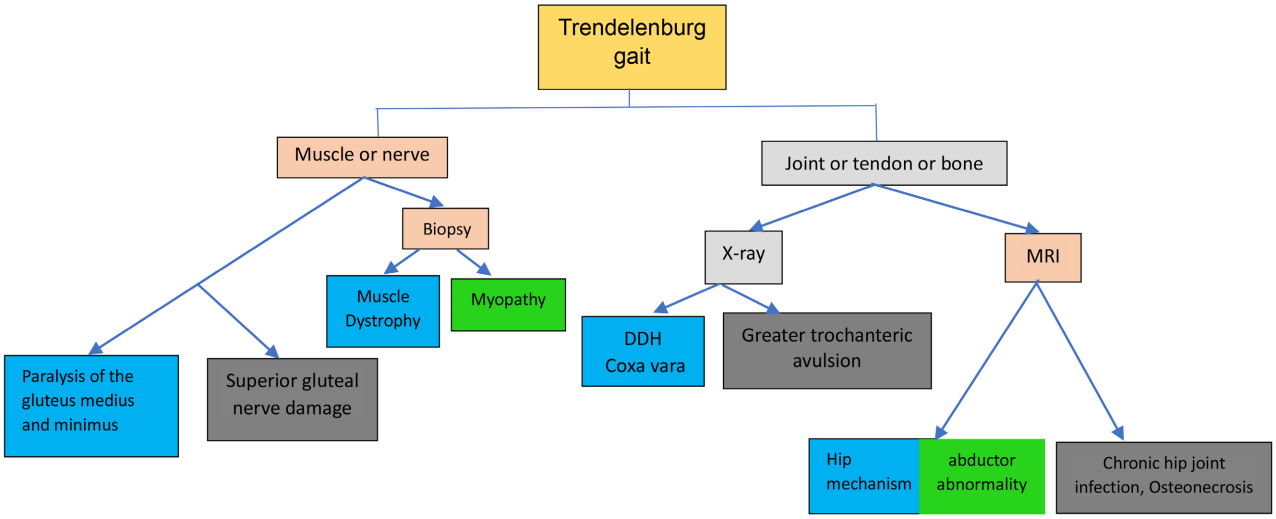


Figure 4. The approach to Equinus gait, Circumduction gait and Trendelenburg gait.

Table 7. The abstract of treatment and follow-up for different limping causes.

Group	Diseases	Intervention	Considerations
Emergencies	Neurovascular compromise	A gentle reduction, angioplasty, or emergency open surgery	
	Septic arthritis	Open joint drainage, antibiotic administration	Reevaluating the response through clinical exam improvement and decreased CRP
	Compartment syndrome	Fasciotomy	3 **As** to doubt: more **A**nalgesia for pain but no relief, **A**nxiety, and **A**gitation
	Slipped capital femoral epiphysis	Emergency fixing surgery	Consider the risk of AVN of the hip
	Open fracture	Immediate wound irrigation, debridement, and fracture stabilization	Do not forget antibiotics prescription and tetanus vaccination update
Overuse injury	Stress fracture	Hard-sole shoe, casting, repair surgery (irrigation and debridement), and antibiotics prescription if needed	Consider nail deformity and osteomyelitis
	Osgood-Schlatter disease Sever disease	Ice pack, anti-inflammatory drugs, activity restriction	Rule out the dangerous causes
	Osteochondritis dissecans	Several months of activity modification and weight limitation, anti-inflammatory drugs	Arthroscopy fixation is needed in unstable cases
Toddlers	DDH	Open surgery	
	Foreign body	Removing the foreign bodies and starting antibiotics	Cover Staphylococcus, Streptococcus, and Pseudomonas if needed
	Toddler fracture	Casting	4 weeks duration of treatment

Continued

	Osteomyelitis	Surgical drainage and debridement, antibiotics prescription	
	Limb deficiency	Corrective surgery	
	Clubfoot		
	Spina bifida		
	Coxa vara	Protective treatment or corrective surgery	Association with metabolic bone diseases or osteomyelitis
3 - 10-year-old children	Legg-Calvé-Perthes disease	Anti-inflammatory drugs, controlled weight-bearing, activity limitation, and physical therapy	Casting and surgery if symptoms continue
	Transient synovitis		7 to 10 days duration of improvement
	Kohler disease		Consider the possibility of impaired blood flow and avascular necrosis
	Charcot-Marie-Tooth disease	Corrective surgery	
	Equinus contracture		
	Idiopathic tight Achilles tendon		
10-year-old children	Diskitis	Anti-inflammatory drugs, rest	
	Tumors	Surgical resection	Pediatric genetic evaluation is needed in some cases like osteochondroma
	Tarsal coalition	Conservative treatment, temporary boot or cast, fusion or resection surgery in severe cases	
	Discoid meniscus	Conservative treatment, meniscectomy in severe cases	
	Juvenile Idiopathic Arthritis (JIA)	Corticosteroid agents, referring to a rheumatologist	
	Malignancies	Immediate biopsy and surgery, referring to an oncologist	

6. Treatment/Follow-Up

Table 7 presents the abstract of treatment and follow-up for different limping causes.

7. Conclusion

Limping is a common complaint in children referring to orthopedic surgeons. There are many differential diagnoses for limping. It is important, therefore, to have a systematic approach in order not to miss any case or dangerous etiology. In this article, we provided a comprehensive and inclusive view of pediatric limping based on antalgic and non-antalgic limping, acute trauma history, sys-

temic symptoms, and different abnormal gaits. Although the symptoms of many causes of limping overlap, especially as children are sometimes unable to provide information, the related algorithms help the physician not to miss any serious diseases and consider all possible conditions.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Herman, M.J. and Martinek, M. (2015) The Limping Child. *Pediatrics in Review*, **36**, 184-197. https://doi.org/10.1542/pir.36.5.184

[2] Balza, R. and Shailam, R. (2015) Pediatric Hip Pain. In: Abujudeh, H., Ed., *Emergency Radiology*, Oxford University Press, Oxford, 271. https://doi.org/10.1093/med/9780190223656.003.0045

[3] Burns, J. and Mubarak, S. (2020) Evaluation of the Limping Child: Current Concept Review. *Journal of the Pediatric Orthopaedic Society of North America*, **2**. https://doi.org/10.55275/JPOSNA-2020-109

[4] Sawyer, J.R. and Kapoor, M. (2009) The Limping Child: A Systematic Approach to Diagnosis. *American Family Physician*, **79**, 215-224.

[5] O'Dowd, D. and Fernandes, J.A. (2016) The Limping Child—What a Pediatrician Should Know? *The Indian Journal of Pediatrics*, **83**, 1259-1265. https://doi.org/10.1007/s12098-016-2167-2

[6] Gopinathan, N.R. and Behera, P. (2019) Gait. In: Dhatt, S.S. and Prabhakar, S., Eds., *Handbook of Clinical Examination in Orthopedics*: *An Illustrated Guide*, Springer, Berlin, 291-299. https://doi.org/10.1007/978-981-13-1235-9_13

[7] Gibson, M.E. and Stork, N. (2021) Gait Disorders. *Primary Care*: *Clinics in Office Practice*, **48**, 395-415. https://doi.org/10.1016/j.pop.2021.04.004

[8] Marschall, A., Prins, K. and Grumløse, S.P. (2022) Drop-Off at the Gate. In: Henderson, L., Bussey, K. and Ebrahim, H.B., Eds., *Early Childhood Education and Care in a Global Pandemic*: *How the Sector Responded*, *Spoke Back and Generated Knowledge*, Routledge, London. https://doi.org/10.4324/9781003257684-8

[9] Joseph, B., Robb, J., Loder, R.T. and Torode, I. (2015) Paediatric Orthopaedic Diagnosis: Asking the Right Questions. Springer, Berlin. https://doi.org/10.1007/978-81-322-2392-4

[10] Kocher, M.S., Zurakowski, D. and Kasser, J.R. (1999) Differentiating between Septic Arthritis and Transient Synovitis of the Hip in Children: An Evidence-Based Clinical Prediction Algorithm. *JBJS*, **81**, 1662-1670. https://doi.org/10.2106/00004623-199912000-00002

[11] Ojukwu, E. anderson, J. and Orandi, A.B. (2020) Child with Fever, Rash, and Abnormal Gait. *Journal of the American College of Emergency Physicians Open*, **1**, 652-653. https://doi.org/10.1002/emp2.12069

[12] Staheli, L.T. (2006) Practice of Pediatric Orthopedics. Lippincott Williams & Wilkins, Philadelphia.

[13] Perry, D.C. and Bruce, C. (2010) Evaluating the Child Who Presents with an Acute Limp. *BMJ*, **341**, c4250. https://doi.org/10.1136/bmj.c4250

[14] Staheli, L.T. (2008) Fundamentals of Pediatric Orthopedics. Lippincott Williams &

Wilkins, Philadelphia.

[15] Raja, H., Khan, S.A. and Waheed, A. (2020) The Limping Child—When to Worry and When to Refer: A GP's Guide. *British Journal of General Practice*, **70**, 467-467. https://doi.org/10.3399/bjgp20X712565

[16] Khubchandani, R. and Khemani, C. (2017) Approach to a Child with a Limp. In: Sawhney, S. and Aggarwal, A., Eds., *Pediatric Rheumatology*: *A Clinical Viewpoint*, Springer, Berlin, 173-180. https://doi.org/10.1007/978-981-10-1750-6_15

[17] Mitchell, P., Viswanath, A., Obi, N., Littlewood, A. and Latimer, M. (2018) A Prospective Study of Screening for Musculoskeletal Pathology in the Child with a Limp or Pseudoparalysis Using Erythrocyte Sedimentation Rate, C-Reactive Protein and MRI. *Journal of Children's Orthopaedics*, **12**, 398-405. https://doi.org/10.1302/1863-2548.12.180004

[18] Ma, N., Sclavos, N., Passmore, E., Thomason, P., Graham, K. and Rutz, E. (2021) Three-Dimensional Gait Analysis in Children Undergoing Gastrocsoleus Lengthening for Equinus Secondary to Cerebral Palsy. *Medicina*, **57**, Article No. 98. https://doi.org/10.3390/medicina57020098

[19] Sutherland, D. (1997) The Development of Mature Gait. *Gait & Posture*, **6**, 163-170. https://doi.org/10.1016/S0966-6362(97)00029-5

[20] Lee, W.-C., Lee, P.-A., Chen, T.-Y., Tsai, Y.-L., Wang, T.-M. and Lu, T.-W. (2022) Bilateral Asymmetry in Balance Control during Gait in Children with Treated Unilateral Developmental Dysplasia of the Hip. *Gait & Posture*, **92**, 223-229. https://doi.org/10.1016/j.gaitpost.2021.11.013

[21] Pavlov, H., Goldman, A. and Freiberger, R. (1980) Infantile Coxa Vara. *Radiology*, **135**, 631-640. https://doi.org/10.1148/radiology.135.3.7384448

[22] Milla, S.S., Coley, B.D., Karmazyn, B., *et al.* (2012) ACR Appropriateness Criteria® Limping Child—Ages 0 to 5 Years. *Journal of the American College of Radiology*, **9**, 545-553. https://doi.org/10.1016/j.jacr.2012.04.017

[23] Vezzetti, R. and Bordoni, B. (2022) Antalgic Gait in Children. StatPearls Publishing, St. Petersburg.

[24] Yagdiran, A., Zarghooni, K., Semler, J.O. and Eysel, P. (2020) Hip Pain in Children. *Deutsches Ärzteblatt International*, **117**, 72-82. https://doi.org/10.3238/arztebl.2020.0072

[25] Essa, M.N., Zhai, K. and King, D. (2022) Dealing with Children and Noncompliant Patients. In: Emara, K.M. and Piuzzi, N.S., Eds., *The Principles of Virtual Orthopedic Assessment*, Springer, Berlin, 133-139. https://doi.org/10.1007/978-3-030-80402-2_10

[26] Fabry, G. (2010) Clinical Practice—The Hip from Birth to Adolescence. *European Journal of Pediatrics*, **169**, 143-148. https://doi.org/10.1007/s00431-009-1025-x

[27] Hassanzadehrad, A. and Aminzadeh, V. (2018) Diskitis as Manifestation of Gait Disturbance. *Iranian Journal of Child Neurology*, **12**, 117.

[28] Wills, A. (2012) Electromyography and Neuromuscular Disorders. Elsevier, Amsterdam, 685 p.

[29] Flynn, J.M. and Widmann, R.F. (2001) The Limping Child: Evaluation and Diagnosis. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, **9**, 89-98. https://doi.org/10.5435/00124635-200103000-00003

[30] Udochkina, L., Vorontsova, O., Goncharova, L. and Mazin, I. (2018) Features of the Space-Time Characteristics of the Gait of Children and Adolescents Involved in Sports. *Sechenov Medical Journal*, No. 3, 12-16.

https://doi.org/10.47093/2218-7332_2018.3.12-16

[31] Chambers, H.G. and Sutherland, D.H. (2002) A Practical Guide to Gait Analysis. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, **10**, 222-231. https://doi.org/10.5435/00124635-200205000-00009

[32] Gourdine-Shaw, M.C., Lamm, B.M., Herzenberg, J.E. and Bhave, A. (2010) Equinus Deformity in the Pediatric Patient: Causes, Evaluation, and Management. *Clinics in Podiatric Medicine and Surgery*, **27**, 25-42. https://doi.org/10.1016/j.cpm.2009.10.003

[33] Requa, E. and Lavallee, M. (2017) The Acutely Limping Child. In: Olympia, R.P., O'Neill, R.M. and Silvis, M.L., Eds., *Urgent Care Medicine Secrets*, Elsevier, Amsterdam, 238-242. https://doi.org/10.1016/B978-0-323-46215-0.00040-9

[34] Vogt, B., Gosheger, G., Wirth, T., Horn, J. and Rödl, R. (2020) Leg Length Discrepancy—Treatment Indications and Strategies. *Deutsches Ärzteblatt International*, **117**, 405-411. https://doi.org/10.3238/arztebl.2020.0405

[35] Rose, R., Fuentes, A., Hamel, B.J. and Dzialo, C.J. (1999) Pediatric Leg Length Discrepancy: Causes and Treatments. *Orthopaedic Nursing*, **18**, 21-31. https://doi.org/10.1097/00006416-199903000-00004

[36] Švehlík, M., Kraus, T., Steinwender, G., Zwick, E.B. and Linhart, W.E. (2012) Pathological Gait in Children with Legg-Calvé-Perthes Disease and Proposal for Gait Modification to Decrease the Hip Joint Loading. *International Orthopaedics*, **36**, 1235-1241. https://doi.org/10.1007/s00264-011-1416-2

[37] Salameh, G. (2015) Waldhof Zentrum, Kinderorthopädie, Kronberg, Deutschland Question Severe Case of Neglected Perthes Disease, Boy 9 Years Old with Pain and Severe Limping. *Radiological Dislocation and Deformed Flattened Femoral Head, Pelvic*, 81, 24-25.

[38] Peck, D., Voss, L.M. and Voss, T.T. (2017) Slipped Capital Femoral Epiphysis: Diagnosis and Management. *American Family Physician*, **95**, 779-784.

[39] Swash, M. and Schwartz, M.S. (2013) Neuromuscular Diseases: A Practical Approach to Diagnosis and Management. Springer Science & Business Media, Berlin.

[40] Caird, M.S., Flynn, J.M., Leung, Y.L., Millman, J.E., Joann, G. and Dormans, J.P. (2006) Factors Distinguishing Septic Arthritis from Transient Synovitis of the Hip in Children: A Prospective Study. *JBJS*, **88**, 1251-1257. https://doi.org/10.2106/JBJS.E.00216

[41] Burns, J. and Mubarak, S. (2020) Evaluation of the Limping Child. *JPOSNA*, **2**, 43. https://doi.org/10.55275/JPOSNA-2020-109

[42] Ilharreborde, B., Bidet, P., Lorrot, M., *et al.* (2009) New Real-Time PCR-Based Method for *Kingella kingae* DNA Detection: Application to Samples Collected from 89 Children with Acute Arthritis. *Journal of Clinical Microbiology*, **47**, 1837-1841. https://doi.org/10.1128/JCM.00144-09

[43] Boutin, R.D., Brossmann, J., Sartoris, D.J., Reilly, D. and Resnick, D. (1998) Update on Imaging of Orthopedic Infections. *Orthopedic Clinics of North America*, **29**, 41-66. https://doi.org/10.1016/S0030-5898(05)70006-7

[44] Morancie, N.A. and Helton, M.R. (2023) Evaluating the Child with a Limp. A*merican Family Physicia*, **107**, 474-485.

[45] Bartoloni, A., Gómez, M.P.A., Cirillo, M., *et al.* (2018) Imaging of the Limping Child. *European Journal of Radiology*, **109**, 155-170. https://doi.org/10.1016/j.ejrad.2018.10.022

[46] Abeynayake, S. and Jackson, M. (2016) Are Two Views of the Pelvis Routinely Re-

quired in the Assessment of the Limping Child? *Sri Lanka Journal of Radiology*, **2**, 10-17. https://doi.org/10.4038/sljr.v2i1.28

[47] Seidman, A.J. and Limaiem, F. (2019) Synovial Fluid Analysis.

[48] Mortazavi, S.J. and Nabian, M.H. (2020) Point-of-Care Ultrasonography in Orthopedics: A Helpful Tool to Improve Patient Care. *Archives of Bone and Joint Surgery*, 8, 323-324.

[49] Visser, F., Sprij, A.J. and Bos, C.F. (2009) Comment on: Clinical Examination versus Ultrasonography in Detecting Developmental Dysplasia of the Hip. *International Orthopaedics*, **33**, 883-884. https://doi.org/10.1007/s00264-008-0706-9

[50] Crow, A., Cheung, A., Lam, A. and Ho, E. (2010) Sonography for the Investigation of a Child with a Limp. *Australasian Journal of Ultrasound in Medicine*, **13**, 23-30. https://doi.org/10.1002/j.2205-0140.2010.tb00160.x

[51] Nadel, H.R. (2010) Pediatric Bone Scintigraphy Update. Elsevier, Amsterdam, 31-40. https://doi.org/10.1053/j.semnuclmed.2009.10.001

[52] Scharf, S. (2009) SPECT/CT Imaging in General Orthopedic Practice. Elsevier, Amsterdam, 293-307. https://doi.org/10.1053/j.semnuclmed.2009.06.002

[53] Akbar, A.H.A., Abdulsattar, O.A. and Al-Bayati, H.A. (2017) Evaluation of Imaging Study Results in Limping Patients Related to Hip. *Medical Journal of Babylon*, **14**, 83-90.

[54] Mazur, J.M., Ross, G., Cummings, J., Hahn Jr., G.A. and McCluskey, W.P. (1995) Usefulness of Magnetic Resonance Imaging for the Diagnosis of Acute Musculoskeletal Infections in Children. *Journal of Pediatric Orthopedics*, **15**, 144-147. https://doi.org/10.1097/01241398-199503000-00002

[55] Lampasi, M., Antonioli, D. and Donzelli, O. (2012) The Limping Child: When to Suspect Spinal Disorders? *Clinical Pediatrics*, **51**, 907-916. https://doi.org/10.1177/0009922812441676