

Anatomical Variations of Groin Pain: A Comprehensive Review of Structural, Neural and Biomechanical Factors



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Abstract

Background: Groin pain represents a significant clinical challenge, accounting for a substantial proportion of time-loss injuries in athletic populations. The complex anatomical architecture of the inguinal region, compounded by substantial inter-individual variation, frequently obscures the pathoanatomical source of pain, hindering accurate diagnosis and effective treatment.

Objective: This article reviews the anatomical variations pertinent to groin pain, focusing on neural branching patterns, gender-based structural differences, hip morphology, and their biomechanical implications. The objective is to synthesize current evidence to provide a framework for clinicians to navigate this complex diagnostic landscape.

Methods: A narrative review was conducted synthesizing data from cadaveric studies, prospective cohort analyses, and biomechanical investigations focusing on the anatomical and functional variations of the groin region.

Results: Significant variations were identified in the innervation patterns of the groin, with cadaveric studies revealing four distinct branching patterns (Types A-D) that are bilaterally symmetric in only 40.6% of individuals. Gender-based anatomical differences in the inguinal canal and pelvic morphology contribute to a higher prevalence of groin pain in male athletes. Hip morphological variations, specifically an alpha angle $>55^\circ$ indicative of Cam-type femoroacetabular impingement (FAI), show a strong association with groin pain. However, biomechanical studies reveal that movement strategies during athletic tasks show no direct correlation with clinically palpated pain locations, highlighting the disconnect between structural variation and functional presentation.

Conclusion: Anatomical variation is the norm in the region. Effective management requires a comprehensive, individualized approach that integrates an understanding of neural variability, gender-specific anatomy, and hip morphology with a detailed clinical examination. Future research should focus on dynamic imaging and personalized rehabilitation protocols to bridge the gap between structural variation and functional outcomes.

Keywords: Groin Pain; Anatomical Variation; Inguinal Neurology; Femoroacetabular Impingement; Sports Hernia; Athletic Pubalgia

Abbreviations: MeSH: Medical Subject Headings; FAI: Femoroacetabular Impingement; PPAC: Prepubic Aponeurotic Complex

Introduction

Groin pain is a pervasive and debilitating condition, particularly prevalent in sports that involve repetitive kicking, cutting, and sudden changes of direction. In soccer, for instance, groin injuries account for 10-18% of all time-loss injuries, representing a significant burden on athletes and healthcare systems alike. Beyond the athletic population, groin pain is a

common presentation in general practice and surgical clinics, often associated with inguinal hernias, urological conditions, or musculoskeletal disorders. The morbidity associated with chronic groin pain is substantial, ranking behind only fractures and joint reconstruction in terms of lost training and play time, and often leading to protracted recovery periods [1-5].

The clinical challenge in managing groin pain is rooted in the region's intricate anatomical complexity. The groin serves as a mechanical and structural crossroads, where the trunk meets the lower limb. The inguinal ligament forms a critical boundary, with the abdominal wall musculature inserting superiorly and the adductor musculature originating inferiorly. The prepubic aponeurotic complex (PPAC) acts as a vital interconnection between these muscle groups, creating a functional continuum that transmits significant forces during athletic activity. Historically, groin pain was often simplistically attributed to a single pathology, such as an inguinal hernia or adductor tendinopathy. However, contemporary understanding recognizes that the pain is often multifactorial, involving a complex interplay of muscular, tendinous, neural, and bony structures.

This complexity is significantly amplified by the substantial anatomical variations that exist between individuals. The variability of the groin region is perhaps most pronounced in its neural architecture. The ilioinguinal, iliohypogastric, and genitofemoral nerves provide sensory innervation to the area, but their pathways, branching patterns, and even their presence can vary considerably from one individual to another, and even between the left and right sides of the same individual. This neural heterogeneity has profound implications, as it explains why pain referral patterns are often poorly localized and why surgical interventions, such as hernia repairs, carry a significant risk of inadvertent nerve injury leading to chronic post-operative pain [6-10].

Furthermore, anatomical variation extends beyond the neural network. Gender-specific differences in the anatomy of the inguinal canal and pelvic morphology influence susceptibility to injury, with male athletes being at a significantly higher risk of developing groin pain syndrome. Similarly, variations in the morphology of the proximal femur, such as those seen in femoroacetabular impingement (FAI), can alter hip joint mechanics and contribute to groin symptoms. This article aims to provide a comprehensive review of the key anatomical variations that contribute to groin pain. By synthesizing evidence from cadaveric studies, clinical cohorts, and biomechanical analyses, we will explore the implications of neural variability, gender-based structural differences, and hip morphology for clinical diagnosis and management. The goal is to underscore that a one-size-fits-all approach is insufficient, and that a nuanced, individualized understanding of anatomy is essential for effective patient care.

Methods

Study Design This study is a narrative review designed to synthesize and interpret existing literature on the anatomical variations of the groin region and their clinical implications for groin pain. A narrative review was chosen to provide a broad, comprehensive overview of a complex and multifaceted topic, integrating findings from diverse fields including anatomy, orthopedics, sports medicine, and biomechanics. **Search Strategy** A systematic literature search was conducted in the following

electronic databases: PubMed, Scopus, and Web of Science. The search was performed for articles published up to August 2026. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and keywords related to the topic. The primary search terms included:

- "Groin pain" OR "Athletic pubalgia" OR "Sports hernia"
- "Anatomical variation" OR "Individual variation"
- "Ilioinguinal nerve" OR "Genitofemoral nerve" OR "Inguinal nerve"
- "Femoroacetabular impingement" OR "Hip morphology" OR "Alpha angle"
- "Gender differences" OR "Sex differences"
- "Biomechanics" OR "Movement strategy"

Boolean operators (AND, OR) were used to combine search terms. The reference lists of all included articles and relevant review papers were manually screened to identify any additional studies not captured in the database search.

Inclusion Criteria Studies were included if they met the following criteria:

- Original research articles (including cadaveric studies, observational cohorts, case-control studies, and biomechanical analyses).
- Review articles and meta-analyses.
- Studies specifically investigated anatomical variations of structures in the groin, hip, or inguinal region.
- Studies explored the relationship between anatomical variations and groin pain or related clinical outcomes.
- Studies published in the English language.

Exclusion Criteria Studies were excluded based on the following criteria:

- Case reports or small case series (n<10) unless they provide unique anatomical insights.
- Opinion pieces, editorials, and conference abstracts.
- Studies focused solely on surgical techniques without anatomical variation data.
- Studies on pathologies not directly related to groin pain (e.g., primary urogenital disorders without musculoskeletal involvement).

Data Extraction and Synthesis Data from the included studies were extracted and organized into thematic categories relevant to the objectives of this review. The key areas of focus were:

Neural Anatomy: Studies detailing branching patterns, prevalence, and symmetry of the ilioinguinal, iliohypogastric, and genitofemoral nerves.

Gender-Based Structural Differences: Research comparing anatomical features of the inguinal region and pelvis between males and females.

Hip Morphology and FAI: Studies on femoral head asphericity (alpha angle) and other bony parameters associated with groin pain.

Biomechanics: Research analyzing movement strategies and their relationship with clinical pain location. Due to the heterogeneous nature of the studies included, a formal meta-analysis was not feasible. Instead, a narrative synthesis was performed, summarizing the findings from the key studies and integrating them to form a coherent clinical overview [11-15].

Results

The synthesis of the reviewed literature yielded significant findings regarding anatomical variations across three primary domains: neural architecture, gender-based structural differences, and hip morphology. The interplay between these structural variations and functional biomechanical strategies was also explored.

1. **Neural Anatomical Variations** The neural innervation of the groin region is characterized by profound variability. A landmark cadaveric study dissecting 64 hemi-pelvises identified four distinct branching patterns for the ilioinguinal and genitofemoral nerves. These patterns dictate the distribution of sensory innervation to the scrotum/labia and the ventromedial thigh.

Type A (43.7% of cases): The genitofemoral nerve is the dominant sensory supplier. The ilioinguinal nerve provides no sensory contribution to the scrotal/labial or thigh regions.

Type B (28.1% of cases): The ilioinguinal nerve is the dominant sensory supplier. The genito-femoral nerve provides motor fibers to the cremaster muscle but lacks sensory branches to the groin.

Type C (20.3% of cases): Both nerves contribute. The ilioinguinal nerve provides sensory branches to the mons pubis and inguinal crease and shares a branch with the iliohypogastric nerve.

Type D (7.8% of cases): Cutaneous branches emerge from both nerves, with the ilioinguinal nerve innervating the mons pubis and inguinal crease.

Critically, this branching pattern was bilaterally symmetric in only 40.6% of the cadavers, meaning that for many individuals, innervation differs between their left and right sides. Further research has identified even more nuanced variations, describing 16 different branching patterns and 8 distinct distribution types for the ilioinguinal nerve alone. In 13% of cases, the genital branch of the genitofemoral nerve and the ilioinguinal nerve merge within the inguinal canal. These findings explain frequently

poorly localized and atypical pain presentations in patients with inguinal-related groin pain.

2. **Gender-Based Structural Differences** A consistent finding across literature is the significant disparity in groin pain prevalence between sexes. Male athletes have a substantially higher risk of developing chronic groin pain compared to their female counterparts. This disparity appears to have a clear anatomical basis.

Inguinal Canal: The contents of the inguinal canal differ markedly between sexes. In males, the canal houses the spermatic cord, which includes the vas deferens, testicular vessels, and the cremasteric muscle. In females, it contains only the round ligament of the uterus. This difference influences the mechanical properties of the posterior wall of the inguinal canal, potentially making it more vulnerable in males.

Pelvic Morphology: The pelvis exhibits distinct sexual dimorphism. While the pubic symphysis is a secondary cartilaginous joint with limited mobility (approximately 1° of rotation and 2 mm of translation), its structural configuration and load distribution patterns differ between sexes. These differences affect how forces from the trunk and lower extremities are transmitted across the anterior pelvis, influencing the stress on the PPAC and adductor origins.

3. **Hip Morphology and Femoroacetabular Impingement (FAI)** The relationship between proximal femoral morphology and groin pain is well-established. Femoroacetabular impingement (FAI), particularly the Cam-type deformity, is a significant contributor. A Cam deformity is characterized by an aspherical femoral head, which causes abnormal contact and shearing forces within the hip joint during flexion and internal rotation. The alpha angle is the primary imaging measurement used to quantify this asphericity. A systematic review confirmed a strong link between an alpha angle exceeding 55° (indicative of Cam-type FAI) and the presence of groin pain in athletes. This morphological variant leads to increased intra-articular stress, which can manifest as groin pain. However, it is crucial to note that while this association is significant, the same review found that other biomechanical parameters, such as the lateral center-edge angle, showed no consistent link to groin pain, suggesting the relationship is highly specific to the Cam-type morphology.

4. **Biomechanical Movement Strategies** While structural variations are crucial, their clinical impact is mediated through movement. A prospective cohort study of 322 athletes with chronic groin pain identified three distinct movement strategies during a change-of-direction task using cluster analysis. These strategies differed in terms of joint kinematics and work distribution:

Cluster 1 (40%): Characterized by increased ankle eversion, knee internal rotation, and external rotation, with greater reliance on knee work.

Cluster 2 (19%): Featured increased hip flexion, contralateral pelvis drop, and greater hip work.

Cluster 3 (41%): Distinguished by high ankle dorsiflexion, ankle work, and prolonged ground contact time.

Paradoxically, these movement clusters showed no correlation with clinically palpated pain locations. This finding indicates that a structurally vulnerable area (e.g., a tight hip flexor or an FAI) does not inevitably lead to a specific, predictable movement strategy. Instead, patients adopt different global movement patterns to compensate, which can either protect or overload specific groin structures, independent of the underlying pathoanatomy.

Discussion

The results of this review underscore a fundamental truth in the management of groin pain: anatomical variation is the rule, not the exception. The complexity of the region, combined with significant inter-individual differences, renders a simplistic, “one-size-fits-all” diagnostic approach inadequate. The discussion will explore the clinical implications of these variations and propose a more nuanced framework for patient assessment and management.

The Neural Puzzle: Implications for Diagnosis and Surgery

The profound variability in the neural anatomy of the groin has direct and significant clinical consequences. The identification of four distinct branching patterns, with bilateral symmetry present in less than half of the population, explains why pain from the same underlying structural pathology can present so differently between patients. For the clinician, this neural complexity means that pain location alone is a poor predictor of the injured structure. A patient presenting with “groin pain” could have nociceptive pain originating from the adductor tendon, the rectus abdominis insertion, or the hip joint. However, they could equally be suffering from neuropathic pain due to compression, traction, or entrapment of the ilioinguinal or genitofemoral nerves, especially if they have a history of inguinal hernia repair or pelvic trauma. The clinical hallmark—a burning or electric sensation—can help differentiate neuropathic from nociceptive pain (which typically presents as dull or stabbing), but the overlapping distribution of these nerves often confounds this distinction.

The surgical implications are equally profound. Inguinal hernia repair is one of the most common surgical procedures worldwide. Chronic post-operative pain, often neuropathic in nature, is a well-recognized complication affecting up to 10% of patients. Knowledge of the variable nerve pathways is critical during surgery to identify and protect these structures. The finding that the ilioinguinal and genitofemoral nerves can merge within the inguinal canal in 13% of cases underscores the need for meticulous dissection. When neuropathic pain is refractory to

conservative management and neurectomy is considered, precise mapping of the patient’s unique neural anatomy is essential to ensure the correct nerve is addressed, and uninvolved nerves are preserved to minimize further sensory loss.

Gender and the Athlete: A Protective or Predisposing Anatomy?

The epidemiological observation that male athletes are at a higher risk of groin pain is supported by the anatomical differences identified in this review. The male inguinal canal, due to the passage of the spermatic cord, has a different structural integrity compared to the female canal. The presence of the spermatic cord creates a natural area of potential weakness that can be subjected to increased intra-abdominal pressure during high-intensity activities like sprinting or jumping, contributing to the development of “sports hernia” (or athletic pubalgia).

Furthermore, sexual dimorphism in pelvic morphology plays a role. A wider pelvis in females alters the Q-angle and the biomechanics of the hip and knee, which might actually distribute forces across the pubic symphysis and surrounding soft tissues differently, potentially reducing the focal stress that predisposes males to adductor and abdominal wall injuries. This does not imply that females are immune to groin pain, but rather that the anatomical vulnerabilities differ, and clinicians must consider these sex-specific risk factors when evaluating patients. A female presenting with groin pain may be more likely to have an intra-articular hip problem, such as a labral tear, or a different pattern of adductor overload.

Discussion (Part 2) The Hip-Groin Nexus: When Morphology Meets Function

The association between Cam-type FAI and groin pain is a well-established paradigm. An alpha angle greater than 55° represents an anatomical variation that places the hip joint at a biomechanical disadvantage. As the femoral neck impinges on the acetabular rim during flexion and internal rotation (positions common in sports like soccer and hockey), it generates shear forces that can lead to labral tears, chondral damage, and subsequent pain, which is often referred to the groin. However, the review highlights a crucial clinical nuance: not everyone with a Cam deformity develops groin pain.

As the lateral center-edge angle showed no consistent link to groin pain, it suggests that FAI symptoms are not purely a matter of bony morphology. The onset and severity of pain likely depend on several other factors, including the patient’s activity level, the range of motion demands of their sport, and their muscle strength and coordination. In athletes, a Cam deformity may remain asymptomatic until a change in training load or an acute injury alters the dynamic stabilizing forces around the hip, tipping the balance toward pathology.

The Movement Disconnect: A Clinical Conundrum

Perhaps the most counterintuitive finding of this review is the lack of correlation between movement strategies and clinical pain location. This finding challenges a fundamental assumption in musculoskeletal medicine: that an injured tissue (e.g., the adductor longus) will result in a predictable compensatory movement pattern (e.g., reduced hip adduction). The cohort study that identified three distinct movement clusters during a change-of-direction task demonstrated that athletes with chronic groin pain exhibit significantly different kinematic profiles.

Some adopt a “hip strategy” with more hip work, others a “knee strategy,” and others an “ankle strategy.” This variance suggests that pain acts as a central nervous system modifier of motor control, leading to the adoption of different “protective” or compensatory strategies based on factors that are unique to the individual, such as past injuries, dominant limb, and proprioceptive acuity. The implication is that a patient with groin pain is not simply a victim of a local tissue injury; they are the product of an interaction between a structurally vulnerable tissue and a globally altered movement pattern.

Clinical Implications for Rehabilitation

This dissociation can also lead to serious clinical implications. In this scenario, a clinician might treat the painful “spot” (i.e., adductor tendon), whereas the real underlying issue is the patient’s faulty movement pattern which was putting excessive strain on this structure. For example, if a patient utilizes a strategy involving excessive hip flexion, and adduction with pelvic drop during movements, simply treating the adductor origin will not be sufficient; the faulty motor pattern should also be addressed.

Therefore, the rehabilitation program should be multi-faceted, aiming to:

Address the tissues presenting the pain (tendon loading etc) and unload the structures. Address the underlying anatomical variation by either mobilizing and strengthening the tissues involved or modifying the load distribution as dictated by the patient’s structural variation. For example, a patient with an FAI type impingement will benefit from increased capsular mobilization and dynamic stability training of the hip joint, to improve the range of motion and offload the impinging structures. Address the faulty global movement patterns by employing video analysis and motor relearning programs to modify the movement pattern. For example, in a patient who has been categorized under the “hip strategy” cluster, the program should focus on modifying excessive hip flexion, and pelvic drop, by encouraging more ankle and knee strategy during activity.

Conclusion

Anatomical variability is the rule, rather than the exception, within the region of the groin, and this has significant implications in terms of diagnosis and management of groin pain. The variation

in the pattern of neural branching most probably accounts for the frequently reported vague radiation of pain in patients with groin injuries. The observed sex differences may explain some of the clinically observed differences in presentation and prognosis between male and female athletes. The presence of Cam-type FAI morphological variants in several patients, along with the wide inter-individual variability of the acetabular morphology, may explain the frequent occurrence of intra-articular pathology in patients presenting with groin pain. However, the individual patient’s movement strategy, which may contribute to abnormal contact/strain patterns within the hip joint, should be considered when designing a rehabilitation program.

The current study demonstrated that the relationship between a structure and a function is not straight forward, and therefore, a purely pathoanatomical approach to diagnosis and management of groin pain is flawed. The need for a more nuanced, person-centred approach to the management of patients with groin pain, based on an in-depth understanding of individual anatomical variation, is evident. For the clinician, this requires a shift in thinking, as an appreciation of anatomical variability and subsequent individual differences in presentation and prognosis is incompatible with the traditional, mechanistic approaches to diagnosis and management of groin pain. The clinician’s role is to perform a comprehensive assessment, which incorporates the understanding of potential anatomical variations and their clinical implications. Specifically, the following three items are recommended:

Clinical examination

A thorough assessment of pain patterns including mapping of tender points, combined with a comprehensive musculoskeletal, neurological and hip joint range of motion examination, is mandatory in every patient with suspected groin injury. This assessment should include palpation of bony landmarks (ASIS, pubic tubercle, “3G point”), soft tissues (adductor origin, rectus abdominis insertion) and a detailed neurological assessment of the L1-L3 nerve root distribution. Specific special tests for hip joint range of motion should be performed to exclude intra-articular pathology, such as the anterior impingement test for FAI.

Imaging

Imaging tests are indicated in patients with suspected intra-articular pathology. MRI is preferred due to its superior ability to delineate soft tissue pathology. However, it should be noted that FAI-related morphological variants (cam type) can only be accurately assessed with targeted imaging (e.g., plain x-ray in Dunn view). A careful interpretation of imaging reports is essential, as normal anatomical variants can be frequently found in asymptomatic hips.

Rehabilitation

A rehabilitation program should be individualized for each patient, based on the findings of the clinical assessment.

A generalized approach, which does not consider individual patient characteristics, is unlikely to be successful. Therefore, the clinicians should consider the use of video analysis to identify a patient's faulty movement pattern. The rehabilitation program should start with the management of acute pain and tissue loading followed by neuromuscular control, stability training of the lumbopelvic-hip region, improved range of motion and modification of faulty movement patterns associated with sport and activity. The principles of sport and performance-specific load management should be introduced when appropriate.

Surgery

In cases of neuropathic pain, which may be resistant to conservative treatment, the surgeons should be mindful of significant anatomical variability of the sensory nerve branches, and neurectomy should be considered only after thorough diagnostic work up by an experienced professional. When indicated, neurectomy should be performed by a surgeon with extensive anatomical knowledge of the region and advanced surgical skills to avoid damage to the other sensory nerve branches.

Future Research Direction

It was beyond the scope of the present study to determine the influence of anatomical variations on the load distribution across the hip joint during activity. However, future research should employ dynamic imaging (e.g. MRI) to elucidate the relationship between anatomy and function. Another important area for future research includes the identification of load patterns during sporting tasks, which may lead to the establishment of key biomechanical predictors of groin injury. The biomechanical risk factors for groin injury and pain, such as altered lower limb and trunk kinematics and faulty load distribution strategies can be used as a basis for developing primary prevention strategies. There is a need for future randomized control trials, which will determine whether a generic rehabilitation program for groin pain is effective compared to an individualized program tailored according to a patient's movement strategy (cluster analysis). Such trials will be critical for future developments in the management of groin pain by individualizing the rehabilitation process and reducing the high recurrence of symptoms.

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