ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

Rehabilitation and therapeutic strategies for non-traumatic knee effusion: An integrative review

Jiaying Zhang[1,a,*], Yuling Bai[1,b], Juanping Xie[1,c], Chao He[1,d]

[1]*School of Medicine, Ankang University, Ankang, Shaanxi, China*
[a]*zhangjiay224@163.com*, [b]*1114365300@qq.com*, [c]*598811587@qq.com*, [d]*3288098649@qq.com*
**Corresponding author*

Abstract: *Non-traumatic knee effusion is a common clinical manifestation of various musculoskeletal and inflammatory disorders, including osteoarthritis, inflammatory arthritis, and crystal-induced arthropathies. It is frequently associated with pain, functional impairment, and disease activity, yet its management is often limited to symptomatic treatment or addressed indirectly through the treatment of underlying conditions. In recent years, increasing evidence has suggested that knee effusion is not merely a secondary phenomenon but an important marker of synovial inflammation and disease progression, particularly in osteoarthritis. Current therapeutic strategies for non-traumatic knee effusion encompass pharmacological interventions, intra-articular procedures, and non-pharmacological approaches. While non-steroidal anti-inflammatory drugs, corticosteroids, and joint aspiration remain widely used to control inflammation and alleviate symptoms, their effects are often transient and associated with potential adverse events. Rehabilitation interventions, including exercise therapy, physical modalities, and biomechanical interventions, have emerged as essential components of comprehensive management by targeting joint mechanics, neuromuscular control, and synovial fluid dynamics. Advances in imaging techniques, particularly musculoskeletal ultrasound, have further facilitated the assessment and monitoring of knee effusion, enabling more individualized and targeted treatment strategies. This review provides a comprehensive overview of the etiology, pathophysiology, assessment, and management of non-traumatic knee effusion, with a particular emphasis on rehabilitation strategies. By integrating pharmacological, interventional, and rehabilitative approaches, this review highlights the importance of a multimodal and individualized management framework. Future research should prioritize standardized outcome measures for knee effusion and high-quality clinical trials to clarify the optimal role of rehabilitation in long-term disease control.*

Keywords: *Knee effusion, Rehabilitation, Osteoarthritis, synovitis, Multimodal management*

1. Introduction

Non-traumatic knee effusion represents a substantial clinical burden, particularly in aging populations. It most commonly occurs in the context of degenerative joint disorders, especially knee osteoarthritis (OA), a condition whose prevalence increases markedly with age and constitutes a major source of musculoskeletal disability worldwide. Large-scale epidemiological analyses have estimated that the global prevalence of knee OA is approximately 16.0% among individuals aged 15 years and older, rising to nearly 23% in those aged 40 years and above, with disease burden increasing progressively with advancing age and modifiable risk factors such as obesity and prior joint injury [1–3].

Notably, the prevalence of knee OA is significantly higher in females than in males. A global meta-analysis reported a female-to-male prevalence ratio of approximately 1.7, indicating a substantially higher disease burden among women[4]. Sex-specific differences have also been consistently observed at the national level. In China, a recent systematic review and meta-analysis reported an overall knee OA prevalence of approximately 28%, with women demonstrating a markedly higher prevalence than men (33.9% vs. 20.5%) [5]. Collectively, these findings indicate that middle-aged and older women represent a population at heightened risk for degenerative knee pathology and its associated manifestations, including synovial effusion.

Imaging-detectable knee effusion is present in a considerable proportion of individuals with early or established OA. In a population-based cohort study of adults with early OA (mean age in the mid-50s), approximately 16% of participants exhibited knee effusion at baseline[6]. Beyond its role as a

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

radiological or clinical sign, knee effusion has been associated with increased healthcare utilization, reduced physical activity levels, and diminished work productivity, underscoring its relevance to both individual patients and healthcare systems.

These age- and sex-specific epidemiological patterns are consistent with global disease burden estimates indicating that the majority of OA-related disability occurs in older adults, particularly women. Age-stratified analyses further demonstrate that disease prevalence increases steadily with advancing age and peaks in older populations, while incidence rates tend to peak in mid-to-late adulthood, typically around 50–54 years in females and 60–64 years in males [1,3]. Together, these trends highlight middle-aged and older adults—especially women—as key populations at elevated risk for knee joint degeneration and its clinical sequelae, including synovial effusion.

From a patient-centered perspective, knee effusion contributes to a symptom burden that extends beyond pain alone. Patients frequently report sensations of joint fullness, instability, and movement-related apprehension, which may limit participation in physical activity and compromise functional recovery. These factors are particularly relevant in rehabilitation settings, where patient engagement, confidence, and adherence are critical determinants of treatment success. Consequently, knee effusion should be regarded as a clinically meaningful therapeutic target rather than a secondary or incidental finding in the management of non-traumatic knee disorders.

1.1. Clinical relevance of non-traumatic knee effusion

Knee effusion represents an abnormal accumulation of synovial fluid within the knee joint and is a frequent finding in both inflammatory and degenerative joint diseases. In the absence of traumatic injury, knee effusion commonly occurs in conditions such as knee osteoarthritis, rheumatoid arthritis, and crystal-induced arthritis, including gout[7-9]. Epidemiological and clinical studies have demonstrated that knee effusion is closely associated with pain severity, functional limitation, and impaired quality of life in patients with chronic knee disorders[6].

Traditionally, non-traumatic knee effusion has been regarded as a secondary manifestation of the underlying disease process. However, accumulating evidence suggests that synovial effusion reflects active synovitis and may play a more direct role in symptom generation and structural progression, particularly in OA[7]. Imaging studies using magnetic resonance imaging and ultrasonography have consistently shown that the presence and extent of knee effusion correlate with synovial inflammation and disease activity[7,10].

1.2. Current challenges in management

The management of non-traumatic knee effusion remains challenging due to its heterogeneous etiology and variable clinical presentation. Pharmacological treatments, including non-steroidal anti-inflammatory drugs (NSAIDs) and corticosteroids, are commonly prescribed to reduce inflammation and relieve pain. Although these agents may provide short-term symptom relief, their long-term use is limited by safety concerns and inconsistent effects on joint structure and recurrent effusion[11–13]. Intra-articular interventions such as joint aspiration and corticosteroid or hyaluronic acid injections may offer temporary benefit but often fail to prevent recurrence of effusion[14,15].

Importantly, non-pharmacological strategies remain underutilized in the management of knee effusion. Rehabilitation interventions are frequently deferred until pain subsides or effusion resolves, despite evidence that appropriately designed exercise and biomechanical interventions can improve joint function, reduce symptoms, and potentially modulate synovial inflammation[16–19]. In addition, the lack of standardized assessment tools for knee effusion and the heterogeneity of outcome measures further complicate clinical decision-making and research synthesis.

1.3. Rationale and objectives of this review

Given the multifactorial nature of non-traumatic knee effusion and its impact on patient outcomes, an integrated management approach is warranted. While previous reviews have primarily focused on disease-specific treatment strategies, few have addressed knee effusion as a distinct clinical entity requiring targeted intervention. In particular, the role of rehabilitation in the management of non-traumatic knee effusion has not been systematically emphasized.

The objective of this review is to summarize current evidence on the etiology, pathophysiology,

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

clinical assessment, and therapeutic options for non-traumatic knee effusion, with a specific focus on rehabilitation strategies. By integrating pharmacological, interventional, and rehabilitative perspectives, this review aims to provide clinicians and researchers with a practical framework for individualized management and to identify key gaps for future research.

2. Etiological classification of non-traumatic knee effusion

Non-traumatic knee effusion is a heterogeneous clinical entity arising from a broad spectrum of underlying pathological processes. Etiological classification is essential for guiding treatment strategies, prognostic evaluation, and rehabilitation planning. Based on current clinical and pathophysiological understanding, non-traumatic knee effusion can be broadly categorized into degenerative, inflammatory, crystal-induced, infectious, and other less common systemic causes.

2.1. Degenerative joint disease–related effusion

Knee osteoarthritis (OA) represents the most common cause of non-traumatic knee effusion, particularly in middle-aged and older adults. Although traditionally regarded as a predominantly "non-inflammatory" arthropathy, accumulating evidence indicates that synovial inflammation plays a central role in OA-related effusion. Low-grade synovitis, characterized by synovial hypertrophy and increased vascular permeability, contributes to excessive synovial fluid production and recurrent effusion[20].

Imaging studies using magnetic resonance imaging and ultrasonography have demonstrated that the presence and extent of knee effusion in OA correlate with synovial inflammation, pain severity, and structural progression[20]. OA-related effusion is typically non-inflammatory or mildly inflammatory in nature; however, its volume may fluctuate with mechanical loading, disease activity, and physical function. This dynamic characteristic highlights the potential role of biomechanical and rehabilitation-based interventions in the long-term management of degenerative knee effusion.

2.2. Inflammatory arthritis–related effusion

Inflammatory arthritides, particularly rheumatoid arthritis (RA), represent important causes of persistent or recurrent non-traumatic knee effusion. In these conditions, immune-mediated synovitis leads to marked synovial hyperplasia, inflammatory cell infiltration, and excessive synovial fluid accumulation, resulting in clinically apparent effusion[8].

Knee effusion in inflammatory arthritis is often associated with pronounced pain, stiffness, and functional limitation and typically presents with inflammatory synovial fluid characterized by elevated leukocyte counts. The presence of knee effusion is generally considered a marker of active disease and inadequate disease control. Although disease-modifying antirheumatic drugs and biologic agents remain the cornerstone of treatment, residual or recurrent effusion may persist despite systemic disease control, underscoring the need for adjunctive local management and rehabilitation strategies[8].

2.3. Crystal-induced arthritis–related effusion

Crystal-induced arthropathies, including gout and calcium pyrophosphate deposition disease, are characterized by acute or subacute episodes of joint inflammation frequently accompanied by marked knee effusion. In these conditions, crystal deposition within the joint space triggers an intense inflammatory response, leading to rapid synovial fluid accumulation[9].

Knee effusion associated with crystal-induced arthritis is typically highly inflammatory and may clinically mimic septic arthritis. Although pharmacological management aimed at controlling acute inflammation and correcting metabolic abnormalities is essential, joint effusion may recur in the absence of sustained disease control. Recurrent effusion in this population may contribute to joint dysfunction, pain-related movement avoidance, and secondary degenerative changes over time.

2.4. Infectious and other systemic causes

Although less common, non-traumatic knee effusion may also result from infectious etiologies, including septic arthritis, particularly in immunocompromised individuals or those with underlying joint disease. These conditions are associated with marked inflammatory effusion and require prompt

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

diagnosis and targeted antimicrobial therapy[21].

In addition, systemic diseases such as sarcoidosis, amyloidosis, and neoplastic processes may rarely present with knee effusion as part of a broader multisystem involvement. While these etiologies fall outside the primary scope of rehabilitation-focused management, early recognition remains essential to ensure timely referral and appropriate treatment.

Given the diverse etiologies of non-traumatic knee effusion, accurate classification based on clinical features, imaging findings, and synovial fluid analysis is critical for optimal management. Importantly, regardless of the underlying cause, persistent knee effusion may contribute to pain, quadriceps inhibition, and functional decline. This highlights the need for comprehensive treatment strategies that integrate medical, interventional, and rehabilitation-based approaches.

3. Pathophysiological mechanisms of non-traumatic knee effusion

The development of non-traumatic knee effusion reflects a complex interaction between synovial inflammation, vascular permeability, and imbalance in synovial fluid production and clearance. Although the initiating triggers vary across different etiologies, several shared pathophysiological mechanisms contribute to excessive fluid accumulation within the knee joint.

3.1. Synovial inflammation and vascular permeability

Synovitis is widely recognized as a central pathological process underlying non-traumatic knee effusion. Inflammatory activation of the synovial membrane leads to synovial hyperplasia, increased angiogenesis, and upregulation of pro-inflammatory mediators, resulting in enhanced microvascular permeability and plasma extravasation into the joint cavity[20].

Importantly, synovial inflammation is not confined to classically inflammatory arthritides. In knee osteoarthritis, low-grade but persistent synovitis has been consistently demonstrated using histological and imaging techniques, challenging the traditional view of OA as a purely degenerative disease [20]. This inflammatory milieu contributes to recurrent effusion even in the absence of overt systemic inflammation and provides a biological rationale for targeting synovial pathology in non-traumatic knee effusion.

3.2. Imbalance between synovial fluid production and clearance

Under physiological conditions, synovial fluid homeostasis is maintained through a balance between fluid secretion by synoviocytes and fluid clearance via capillary reabsorption and lymphatic drainage. In pathological states, inflammatory stimulation leads to increased synovial fluid production that may exceed the clearance capacity of the joint, resulting in effusion[7].

Emerging evidence suggests that impaired fluid clearance mechanisms may contribute to the persistence of joint swelling in chronic joint diseases. Clinical observations indicate that effusion may persist despite adequate suppression of systemic inflammation, suggesting that alterations in local joint fluid dynamics play an important role in chronic or recurrent knee effusion [6].

3.3. Mechanical factors and neuromuscular inhibition

Mechanical loading and joint biomechanics play a significant role in modulating synovial inflammation and fluid dynamics. Abnormal joint alignment, altered gait patterns, and muscle weakness can increase focal joint stress, thereby exacerbating synovial irritation and promoting fluid accumulation, particularly in degenerative conditions such as knee osteoarthritis[21].

Moreover, knee effusion itself can induce arthrogenic muscle inhibition, most notably affecting the quadriceps muscle. This reflexive inhibition reduces muscle activation, compromises joint stability, and may further increase abnormal joint loading[22]. Such neuromuscular impairment can create a vicious cycle in which effusion-induced muscle inhibition perpetuates synovial inflammation and recurrent effusion.

3.4. Neurogenic and biochemical contributors

In addition to inflammatory and mechanical factors, neurogenic mechanisms may also contribute to

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

the development and persistence of knee effusion. Altered sensory input from the joint and heightened nociceptive signaling can influence vascular regulation and synovial activity, potentially enhancing vascular permeability and joint swelling [22].

Biochemical alterations within the synovial environment, including sustained production of inflammatory mediators, may persist even when clinical symptoms fluctuate. These ongoing biochemical changes may help explain the chronic and relapsing nature of non-traumatic knee effusion observed in clinical practice [20].

3.5. Implications for rehabilitation and multimodal management

Understanding the multifactorial pathophysiology of non-traumatic knee effusion has important clinical implications. While pharmacological and interventional treatments primarily target inflammatory pathways, rehabilitation interventions can address mechanical, neuromuscular, and circulatory factors that contribute to fluid accumulation.

Exercise therapy, biomechanical correction, and neuromuscular retraining may improve muscle activation, optimize joint loading, and facilitate synovial fluid redistribution, thereby complementing medical management strategies[16-19]. Collectively, these mechanisms highlight the need for a multimodal and individualized treatment approach that integrates pharmacological control of inflammation with targeted rehabilitation strategies to achieve sustained reduction of knee effusion and improvement in functional outcomes.

4. Clinical assessment and outcome measures

Accurate clinical assessment and appropriate outcome measures are essential for the diagnosis, monitoring, and management of non-traumatic knee effusion. Given its heterogeneous etiology and fluctuating clinical course, a comprehensive evaluation combining clinical examination, patient-reported outcomes, imaging modalities, and, when indicated, synovial fluid analysis is required to inform individualized treatment strategies and assess therapeutic response.

4.1. Clinical examination and patient-reported outcome measures

Clinical examination remains the initial step in the assessment of knee effusion. Common physical findings include visible joint swelling, reduced range of motion, and positive fluctuation or patellar tap tests. However, physical examination alone may underestimate the presence or volume of effusion, particularly in individuals with obesity or chronic low-grade synovitis[10]. Moreover, clinical detection of effusion does not reliably distinguish between inflammatory and non-inflammatory etiologies.

Patient-reported outcome measures (PROMs) play a central role in evaluating symptom severity and functional limitation associated with knee effusion. Composite pain and function scores are widely used in both clinical practice and research to capture the impact of joint swelling on daily activities and quality of life[18]. Although PROMs do not directly quantify effusion, they provide clinically meaningful information regarding patient-perceived disability and are commonly employed as primary or secondary endpoints in rehabilitation studies.

Importantly, knee effusion has been shown to contribute to quadriceps inhibition and impaired neuromuscular control, which may not be fully reflected by pain-based outcome measures alone [22]. This limitation highlights the importance of integrating functional performance assessments with patient-reported outcomes in rehabilitation-oriented evaluation.

4.2. Imaging-based assessment

4.2.1. Ultrasonography

Musculoskeletal ultrasonography has emerged as a preferred imaging modality for the assessment of knee effusion due to its accessibility, cost-effectiveness, and capacity for real-time evaluation. Ultrasonography allows sensitive detection and semi-quantitative grading of joint effusion and synovial hypertrophy and has been shown to outperform clinical examination in identifying low-volume effusions [10].

In addition, Doppler ultrasonography enables assessment of synovial vascularity as a surrogate

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

marker of inflammatory activity. These features make ultrasonography particularly valuable for longitudinal monitoring and for guiding interventional procedures such as joint aspiration or intra-articular injection. In rehabilitation settings, ultrasonography may also facilitate monitoring of effusion dynamics in response to exercise-based interventions.

4.2.2. Magnetic resonance imaging

Magnetic resonance imaging (MRI) provides comprehensive visualization of intra-articular structures, including synovium, cartilage, bone marrow, and periarticular tissues. MRI-detected synovitis and effusion have been associated with symptom severity and structural disease progression in knee osteoarthritis[7,21]. Unlike ultrasonography, MRI enables simultaneous evaluation of coexisting pathological features, such as bone marrow lesions or meniscal abnormalities, which may influence treatment planning.

Nevertheless, routine use of MRI is limited by cost, availability, and feasibility for repeated assessments. Consequently, MRI is more commonly applied in research contexts or complex clinical scenarios rather than for routine follow-up in rehabilitation practice.

4.3. Synovial fluid analysis

Synovial fluid analysis remains an important diagnostic tool in the etiological evaluation of non-traumatic knee effusion, particularly when inflammatory, crystal-induced, or infectious causes are suspected. Assessment typically includes evaluation of fluid appearance, leukocyte count and differential, crystal identification, and microbiological studies when infection is a concern [14].

Based on cellular composition, synovial effusions can be broadly classified as non-inflammatory, inflammatory, or septic, providing critical guidance for treatment selection and urgency of intervention. In addition, research interest has increasingly focused on synovial fluid biomarkers as indicators of disease activity and potential predictors of treatment response, although their routine clinical application remains limited [23].

4.4. Outcome measures in clinical trials and rehabilitation research

A major challenge in knee effusion research is the lack of standardized outcome measures. While many studies prioritize pain intensity and global functional scores, fewer investigations include effusion-specific parameters such as effusion volume, synovial thickness, or Doppler signal activity. This heterogeneity limits comparability across studies and complicates evidence synthesis.

For rehabilitation research in particular, combining imaging-based assessments with functional performance measures and patient-reported outcomes may provide a more comprehensive evaluation of treatment efficacy. The development and adoption of standardized, reproducible outcome measures for knee effusion should therefore be prioritized in future clinical trials to better capture the multidimensional effects of therapeutic interventions.

5. Pharmacological and interventional treatments

Pharmacological and interventional treatments play an important role in the short-term management of non-traumatic knee effusion, primarily by suppressing synovial inflammation, alleviating pain, and reducing joint swelling. However, their effects are often transient, and sustained control of effusion frequently requires integration with non-pharmacological and rehabilitation-based strategies.

5.1. Non-steroidal anti-inflammatory drugs

Non-steroidal anti-inflammatory drugs (NSAIDs) are commonly used as first-line agents for symptom relief in patients with knee effusion associated with degenerative and inflammatory joint diseases. By inhibiting cyclooxygenase activity and reducing prostaglandin synthesis, NSAIDs effectively alleviate pain and inflammation and may result in short-term reductions in joint swelling [11].

Despite their analgesic and anti-inflammatory effects, NSAIDs have limited impact on long-term disease progression or recurrent effusion. In addition, gastrointestinal, cardiovascular, and renal adverse effects restrict prolonged use, particularly in older adults with knee osteoarthritis[12]. Consequently, NSAIDs are best considered short-term adjuncts rather than definitive therapies for persistent knee

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

effusion.

5.2. Corticosteroid therapy

5.2.1. Systemic corticosteroids

Systemic corticosteroids may be used selectively in patients with inflammatory arthritis presenting with significant knee effusion. Their potent anti-inflammatory effects can rapidly suppress synovitis and reduce fluid accumulation. However, long-term systemic corticosteroid therapy is generally discouraged due to well-recognized adverse effects, including metabolic disturbances, osteoporosis, and increased infection risk [8].

5.2.2. Intra-articular corticosteroid injections

Intra-articular corticosteroid injections are frequently employed to achieve rapid symptom relief in patients with knee effusion, particularly in osteoarthritis and inflammatory arthritis. Randomized controlled trials have demonstrated short-term improvements in pain and function following intra-articular corticosteroid administration[13]. Reductions in effusion volume often parallel symptomatic improvement, although these effects are typically temporary.

Concerns have been raised regarding the potential negative impact of repeated corticosteroid injections on cartilage integrity. As a result, current guidelines recommend cautious use, emphasizing limited injection frequency and careful patient selection [15].

5.3. Disease-modifying pharmacological therapies

In inflammatory arthritides such as rheumatoid arthritis, disease-modifying antirheumatic drugs and biologic agents remain the cornerstone of treatment. Effective systemic disease control is often accompanied by improvement or resolution of knee effusion through suppression of synovial inflammation[8]. Nevertheless, localized effusion may persist despite systemic remission, reflecting the complex interaction between systemic inflammatory activity and local joint pathology.

In crystal-induced arthritis, pharmacological strategies aimed at controlling urate metabolism or crystal deposition are essential for preventing recurrent inflammatory flares and associated effusion. However, these treatments primarily address disease etiology and do not directly target biomechanical or neuromuscular contributors to joint swelling [9].

5.4. Arthrocentesis and intra-articular injections

Arthrocentesis serves both diagnostic and therapeutic purposes in the management of non-traumatic knee effusion. Therapeutic aspiration can provide immediate symptomatic relief by reducing intra-articular pressure and improving joint mobility, while simultaneously allowing synovial fluid analysis to guide etiological diagnosis and treatment planning [14].

Intra-articular hyaluronic acid injections have been investigated as adjunctive treatments, with some studies reporting modest improvements in pain and function in selected patients. However, evidence regarding their effects on effusion volume remains inconsistent [15]. Regenerative therapies such as platelet-rich plasma have also attracted interest, but current evidence is heterogeneous and standardized protocols are lacking, limiting definitive conclusions regarding their role in effusion management [24].

5.5. Complementary and traditional medicine approaches

Complementary and traditional medicine approaches, particularly those derived from Traditional Chinese Medicine (TCM), have been explored as adjunctive therapies for knee osteoarthritis, a condition frequently accompanied by effusion. Systematic reviews suggest that acupuncture, alone or combined with Chinese herbal medicine, may provide short-term improvements in pain and function in patients with knee OA [25].

However, evidence specifically addressing the effects of TCM interventions on knee effusion remains limited, and methodological heterogeneity across studies precludes firm conclusions. Accordingly, such approaches should be considered complementary options rather than primary treatments and should be integrated cautiously within a comprehensive, evidence-based management framework [26].

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

5.6. Limitations of pharmacological and interventional approaches

While pharmacological and interventional treatments play an essential role in acute symptom control, they often fail to address the mechanical, neuromuscular, and circulatory factors that contribute to persistent or recurrent knee effusion. Repeated injections or prolonged medication use may expose patients to cumulative risks without providing sustained benefit.

These limitations underscore the importance of a multimodal management strategy in which pharmacological and interventional treatments are combined with rehabilitation-based interventions to achieve durable control of knee effusion and optimize functional outcomes.

6. Rehabilitation strategies for non-traumatic knee effusion

Rehabilitation interventions play a pivotal role in the comprehensive management of non-traumatic knee effusion. In contrast to pharmacological and interventional treatments that primarily target inflammatory pathways, rehabilitation strategies address biomechanical, neuromuscular, and circulatory contributors to persistent or recurrent joint swelling. When appropriately individualized according to disease stage and patient characteristics, rehabilitation can facilitate synovial fluid clearance, reduce abnormal joint loading, and improve long-term functional outcomes.

6.1. Rationale for rehabilitation intervention

The presence of knee effusion is closely associated with impaired muscle activation, altered joint mechanics, and functional decline. Arthrogenic muscle inhibition, particularly affecting the quadriceps, is a well-established consequence of knee effusion and contributes to reduced joint stability and abnormal loading patterns[22]. These neuromuscular and biomechanical alterations may perpetuate synovial irritation and fluid accumulation, thereby creating a self-sustaining cycle of effusion and dysfunction.

Rehabilitation interventions aim to interrupt this cycle by restoring neuromuscular control, optimizing joint loading, and enhancing synovial fluid circulation. Importantly, emerging evidence supports the initiation of appropriately modified rehabilitation even in the presence of mild to moderate effusion, challenging the traditional view that exercise therapy should be deferred until complete resolution of joint swelling.

6.2. Physical modalities

Physical modalities are frequently used to support symptom control and facilitate participation in rehabilitation programs. Cryotherapy is commonly applied during acute or highly inflammatory phases to reduce pain and local blood flow, which may indirectly limit further fluid accumulation. Although evidence regarding its direct effect on effusion volume is limited, cryotherapy can enable earlier engagement in therapeutic exercise by alleviating pain and discomfort[16].

Thermotherapy is generally reserved for subacute or chronic stages, where muscle relaxation and improved tissue extensibility are desired[27]. Other modalities, including therapeutic ultrasound, neuromuscular electrical stimulation, and low-level laser therapy, have been investigated in knee osteoarthritis and inflammatory joint conditions. Systematic reviews suggest modest benefits for pain and function; however, high-quality evidence specifically addressing knee effusion outcomes remains limited. Accordingly, physical modalities should be considered adjunctive rather than standalone interventions.

6.3. Exercise therapy

Exercise therapy constitutes the cornerstone of rehabilitation for non-traumatic knee effusion, with benefits extending beyond symptom relief to improvements in muscle strength, joint stability, proprioception, and overall physical function.

6.3.1. Exercise during the acute effusion phase

During periods of active effusion, exercise programs should prioritize joint protection and neuromuscular activation. Isometric strengthening, gentle range-of-motion exercises, and low-load closed-chain activities can be safely implemented to maintain muscle activation without exacerbating

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

joint swelling. Close monitoring of symptom response and effusion status is essential to ensure appropriate load progression.

6.3.2. Exercise during the chronic or recurrent phase

In patients with chronic or recurrent knee effusion, progressive resistance training targeting the quadriceps, hamstrings, and hip musculature is strongly recommended. High-quality randomized controlled trials and systematic reviews have consistently demonstrated that structured exercise programs improve pain, function, and quality of life in knee osteoarthritis [18,19,28]. Although effusion is often a secondary outcome in these studies, improvements in neuromuscular function and joint mechanics are likely to contribute to reduced recurrence of effusion.

Neuromuscular training and movement retraining further address aberrant movement patterns and joint loading, which are particularly relevant in degenerative joint disease. Aerobic exercise, such as walking and cycling, may also confer systemic anti-inflammatory effects and support overall joint health.

6.4. Biomechanical interventions

Biomechanical interventions aim to reduce excessive joint loading and synovial irritation that may contribute to knee effusion. Knee bracing, particularly valgus or unloader braces, has been shown to reduce pain and improve function in selected patients with knee osteoarthritis[29]. While direct evidence regarding reductions in effusion volume is limited, improved load distribution and joint alignment may indirectly mitigate synovial stress.

Foot orthoses and footwear modifications can further influence lower limb biomechanics and may be considered in patients with malalignment or gait abnormalities. These interventions are most effective when integrated into a comprehensive rehabilitation program rather than applied in isolation.

6.5. Integration of rehabilitation into multimodal management

Rehabilitation should be regarded as an essential component of multimodal management for non-traumatic knee effusion rather than a secondary or optional intervention. Optimal outcomes are achieved when rehabilitation is coordinated with pharmacological and interventional treatments—for example, initiating exercise therapy following joint aspiration or intra-articular injection to capitalize on temporary reductions in pain and swelling.

Emerging interest has focused on imaging-informed rehabilitation, particularly the use of musculoskeletal ultrasound to monitor effusion dynamics and guide load progression. Although preliminary data are promising, further research is required to establish standardized rehabilitation protocols and clarify their long-term effects on effusion control and functional recovery.

7. Multimodal and individualized management approaches

The management of non-traumatic knee effusion is inherently complex due to its multifactorial etiology and heterogeneous clinical presentation. No single intervention is sufficient to achieve sustained control of joint effusion across all patient populations. Consequently, a multimodal and individualized management approach is essential, integrating pharmacological, interventional, and rehabilitative strategies according to disease mechanisms, symptom severity, and patient-specific factors[7,8,30].

7.1. Principles of multimodal management

Multimodal management aims to target complementary aspects of knee effusion pathophysiology. Pharmacological and interventional treatments primarily address synovial inflammation and acute symptom burden, while rehabilitation interventions target biomechanical dysfunction, neuromuscular impairment, and impaired synovial fluid dynamics[16,20,22]. Coordinated implementation of these modalities may enhance overall treatment efficacy and reduce reliance on repeated pharmacological interventions [15,28].

Clinical decision-making should consider the phase of effusion (acute versus chronic), the inflammatory profile, and the patient's functional status. For example, joint aspiration or intra-articular

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

corticosteroid injection may be indicated during acute inflammatory flares to rapidly reduce pain and swelling, thereby enabling early initiation or progression of rehabilitation interventions[13-15]. Conversely, in patients with chronic or recurrent effusion, emphasis should be placed on long-term rehabilitation strategies aimed at optimizing joint mechanics, neuromuscular control, and load distribution to prevent recurrence [18,22].

7.2. Disease-specific management considerations

Individualized management strategies should be tailored to the underlying etiology of knee effusion.

In knee osteoarthritis, multimodal management typically combines short-term pharmacological symptom control with structured exercise therapy and biomechanical interventions. Weight management, muscle strengthening, and movement retraining are critical components of long-term care, as mechanical overload and neuromuscular dysfunction play prominent roles in symptom persistence and effusion recurrence[7,17,28]. Rehabilitation-based interventions may reduce the frequency of acute exacerbations and limit the need for repeated intra-articular injections [15,18].

In inflammatory arthritis, effective systemic disease control using disease-modifying antirheumatic drugs (DMARDs) or biologic agents remains the cornerstone of management [8]. However, localized knee effusion may persist despite systemic remission. In such cases, targeted local interventions combined with rehabilitation may help address residual joint dysfunction, prevent secondary degenerative changes, and improve functional outcomes[20,22]. Close collaboration between rheumatologists, rehabilitation specialists, and orthopedic clinicians is essential to optimize individualized care.

In crystal-induced arthritis, acute management focuses on controlling inflammation and pain, while long-term strategies aim to prevent crystal deposition through metabolic control [9,31]. Rehabilitation may play a supportive role in restoring joint function following acute attacks and mitigating the cumulative effects of recurrent inflammation on joint biomechanics and muscle performance.

Adherence represents a critical determinant of rehabilitation effectiveness. Strategies to enhance adherence—including patient education, goal setting, and self-management support—should be integrated into rehabilitation programs. Emerging digital health technologies and remote monitoring tools may further support long-term engagement and outcome tracking, particularly in chronic and recurrent conditions [10,22].

7.3. Role of imaging and biomarkers in individualized care

Advances in imaging techniques have enhanced the ability to individualize management strategies for knee effusion. Musculoskeletal ultrasound, in particular, enables dynamic assessment of effusion volume, synovial hypertrophy, and vascularity, facilitating treatment monitoring and timely adjustment of interventions [10]. Ultrasound-guided procedures may improve the accuracy and safety of joint aspiration and intra-articular injections compared with landmark-based techniques [14].

Emerging research has explored the use of synovial fluid and serum biomarkers to characterize inflammatory activity and predict treatment response. Biomarkers related to cartilage degradation and synovial inflammation have shown potential utility in osteoarthritis and inflammatory arthritis, although their clinical application remains largely investigational and requires further validation before routine implementation [23].

7.4. Challenges and future directions in individualized management

Despite growing recognition of the importance of multimodal care, several challenges remain. Evidence supporting specific combinations or sequencing of interventions is limited, and standardized clinical pathways for managing non-traumatic knee effusion are lacking[28]. Additionally, patient adherence to long-term rehabilitation programs remains a significant barrier to sustained improvement.

Future research should prioritize the development of individualized management algorithms that integrate clinical assessment, imaging findings, and functional outcomes. Pragmatic clinical trials evaluating integrated treatment strategies and real-world effectiveness are needed to inform evidence-based recommendations and optimize long-term management of non-traumatic knee effusion.

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

8. Emerging therapies and future research directions

Advances in the understanding of joint inflammation, imaging techniques, and regenerative medicine have prompted the exploration of novel therapeutic approaches for non-traumatic knee effusion. Although many of these strategies remain investigational, they offer potential avenues for improving long-term effusion control and functional outcomes beyond conventional pharmacological and rehabilitative interventions.

8.1. Biologic and targeted therapies

In inflammatory arthritides, biologic agents targeting specific cytokines, such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6), have demonstrated substantial efficacy in controlling synovitis and joint swelling at the systemic level [8]. Effective systemic disease control often leads to a reduction in knee effusion; however, residual or localized effusion may persist despite clinical remission. This phenomenon highlights the dissociation between systemic inflammatory control and local joint pathology and suggests a potential role for targeted local therapies in conjunction with systemic biologics.

In osteoarthritis, growing interest has focused on disease-modifying osteoarthritis drugs (DMOADs) aimed at modulating inflammatory, catabolic, and metabolic pathways involved in joint degeneration. Although no DMOAD has yet been approved for clinical use, ongoing clinical trials targeting inflammatory mediators, subchondral bone remodeling, and cartilage metabolism may indirectly influence synovial inflammation and effusion dynamics [7,20]. Whether these agents can achieve sustained reductions in knee effusion remains an important area for future investigation.

8.2. Regenerative and injectable therapies

Regenerative approaches, particularly platelet-rich plasma (PRP) and mesenchymal stem/stromal cell (MSC) therapies, have gained increasing attention in the management of knee osteoarthritis. Meta-analyses suggest that PRP injections may provide improvements in pain and functional outcomes in selected patient populations; however, evidence regarding their effects on knee effusion is inconsistent and highly variable across studies [24]. Differences in PRP preparation methods, leukocyte content, dosing protocols, and outcome measures contribute substantially to this heterogeneity.

MSC-based therapies hold theoretical promise due to their immunomodulatory, anti-inflammatory, and trophic effects on joint tissues. Preliminary clinical studies indicate potential benefits in reducing synovial inflammation and improving symptoms; nevertheless, robust data specifically addressing effusion-related outcomes are currently lacking. High-quality randomized controlled trials with standardized cell sources, delivery methods, and effusion-specific endpoints are required before these therapies can be recommended for routine clinical use.

8.3. Imaging-guided and technology-assisted interventions

The integration of advanced imaging techniques into clinical practice has opened new possibilities for individualized management of knee effusion. Musculoskeletal ultrasound enables real-time assessment of effusion volume, synovial hypertrophy, and vascularity, facilitating image-guided aspiration, intra-articular injection, and longitudinal monitoring of treatment response [10]. Compared with landmark-based approaches, ultrasound-guided interventions may improve procedural accuracy, safety, and patient outcomes [14].

Emerging technologies, including wearable sensors, mobile health applications, and digital rehabilitation platforms, may further enhance individualized care by enabling objective monitoring of physical activity levels, joint loading patterns, and adherence to exercise programs. Although their application in knee effusion management remains in an early stage, these tools may support personalized rehabilitation strategies, early detection of symptom exacerbation, and long-term disease monitoring.

8.4. Research gaps and future directions

Despite increasing interest in innovative therapeutic strategies, several critical research gaps remain. First, knee effusion is frequently treated as a secondary or exploratory outcome in clinical trials,

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

resulting in inconsistent reporting and limited comparability across studies. Future research should prioritize standardized and validated effusion-related outcome measures, incorporating both imaging-based assessments and clinically meaningful endpoints.

Second, the optimal sequencing and combination of pharmacological, interventional, and rehabilitative treatments remain poorly defined. Pragmatic clinical trials evaluating integrated, multimodal treatment pathways are needed to inform evidence-based clinical decision-making. Such studies should incorporate patient-centered outcomes, long-term effusion control, functional recovery, and cost-effectiveness.

Finally, further investigation is warranted to elucidate the mechanisms by which rehabilitation interventions influence synovial inflammation, lymphatic drainage, and joint fluid dynamics. Improved mechanistic understanding may facilitate the development of targeted rehabilitation protocols and enable identification of patient subgroups most likely to benefit from specific therapeutic strategies.

9. Conclusions

Although epidemiological data specifically addressing knee effusion remain limited, evidence derived from knee osteoarthritis provides a valuable population-level framework for understanding effusion risk and its clinical implications. Non-traumatic knee effusion is a common yet frequently underrecognized manifestation of a broad spectrum of musculoskeletal and inflammatory disorders. Rather than representing a passive byproduct of underlying joint pathology, knee effusion reflects active synovial processes and contributes directly to pain, functional limitation, and potentially disease progression. Its heterogeneous etiology and multifactorial pathophysiology underscore the need for comprehensive and individualized management strategies.

Pharmacological and interventional treatments play an essential role in short-term symptom relief and suppression of synovial inflammation. However, these approaches alone are often insufficient to achieve sustained control of knee effusion. Rehabilitation-based interventions, by targeting biomechanical dysfunction, neuromuscular inhibition, and impaired joint fluid dynamics, constitute a critical component of long-term management. When effectively integrated with medical and interventional therapies, rehabilitation may reduce effusion recurrence, enhance functional recovery, and support durable clinical improvement.

This review emphasizes the importance of a multimodal and patient-centered framework for managing non-traumatic knee effusion, positioning rehabilitation as an integral rather than adjunctive element of care. Future research should prioritize the development of standardized and validated outcome measures for knee effusion, clarify the optimal sequencing and combination of multimodal interventions, and further elucidate the mechanisms by which rehabilitation influences synovial inflammation and joint fluid homeostasis. Advancing these areas will be essential for strengthening the evidence base and improving clinical outcomes for patients with non-traumatic knee effusion.

Acknowledgement

This work was supported by the Science and Technology Bureau of Ankang City, Shaanxi Province, China (Grant No.AK2025-SF-20).

References

[1] Cui A, Li H, Wang D, Zhong J, Chen Y, Lu H, et al. Global, regional prevalence, incidence and risk factors of knee osteoarthritis: a systematic analysis. EClinicalMedicine. 2020;29–30:100587.
[2] Cross M, Smith E, Hoy D, et al. The global burden of hip and knee osteoarthritis: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis. 2014;73(7):1323–1330.
[3] Wallace IJ, Worthington S, Felson DT, et al. Knee osteoarthritis has doubled in prevalence since the mid-20th century. Proc Natl Acad Sci U S A. 2017;114(35):9332–9336.
[4] Srikanth VK, Fryer JL, Zhai G, et al. A meta-analysis of sex differences in prevalence, incidence and severity of osteoarthritis. Osteoarthritis Cartilage. 2005;13(9):769–781.
[5] Li X, Zhang Y, Wang J, et al. Prevalence of knee osteoarthritis in China: a systematic review and meta-analysis, 2013–2023.J Orthop Surg Res. 2024;19:112.
[6] Cibere J, Kopec JA, Wong H, Singer J, Esdaile JM. Knee effusion is a risk factor for prevalence

ISSN 2616-5791 Vol. 7, Issue 4: 8-20, DOI: 10.25236/AJMHS.2026.070402

and progression of bone marrow lesions: a population-based study. Ann Rheum Dis. 2010;69(5):915–920.
[7] Hunter DJ, Bierma-Zeinstra S. Osteoarthritis. Lancet. 2019;393(10182):1745–1759.
[8] Smolen JS, Aletaha D, McInnes IB. Rheumatoid arthritis. Lancet. 2016;388(10055):2023–2038.
[9] Dalbeth N, Merriman TR, Stamp LK. Gout. Lancet. 2016;388(10055):2039–2052.
[10] D'Agostino MA, Wakefield RJ, Berner-Hammer H, et al. Value of ultrasonography for detection of synovitis in rheumatoid arthritis: a comparison with clinical examination. Ann Rheum Dis. 2005;64(9):1310–1316.
[11] Bjordal JM, Ljunggren AE, Klovning A, et al. NSAIDs, including cyclooxygenase-2 inhibitors, in osteoarthritic knee pain: meta-analysis of randomised placebo-controlled trials. BMJ. 2004;329:1317.
[12] Pavelka K.NSAIDs in the treatment of osteoarthritis. Curr Med Res Opin. 2012;28(8):1231–1239.
[13] McAlindon TE, LaValley MP, Harvey WF, et al. Effect of intra-articular triamcinolone vs saline on knee cartilage volume and pain in patients with knee osteoarthritis: a randomized clinical trial.JAMA. 2017;317(19):1967–1975.
[14] Roberts WN, Hedges JR. Arthrocentesis and injection of the knee joint. Am Fam Physician. 2002;66(8):1497–1500.
[15] Bannuru RR, Natov NS, Obadan IE, et al. Therapeutic trajectory following intra-articular hyaluronic acid injection in knee osteoarthritis: a meta-analysis. Ann Intern Med. 2015;162(1):46–54.
[16] Riis RGC, Henriksen M, Klokker L, et al. The effects of exercise on synovial inflammation in knee osteoarthritis: a randomized controlled trial. Arthritis Rheumatol. 2017;69(5):943–952.
[17] Fransen M, McConnell S, Harmer AR, et al. Exercise for osteoarthritis of the knee.Cochrane Database Syst Rev. 2015;(1):CD004376.
[18] Bennell KL, Buchbinder R, Hinman RS. Physical therapies in the management of osteoarthritis: current state of the evidence. JAMA. 2014;311(9):955–956.
[19] Moyer RF, Birmingham TB, Bryant DM, et al. Biomechanical interventions for knee osteoarthritis: a systematic review.Arthritis Care Res (Hoboken). 2015;67(5):667–679.
[20] Scanzello CR, Goldring SR. The role of synovitis in osteoarthritis pathogenesis. Bone. 2012;51(2):249–257.
[21] Sharma L.Osteoarthritis of the knee.N Engl J Med. 2021;384(1):51–59.
[22] Rice DA, McNair PJ.Quadriceps arthrogenic muscle inhibition: neural mechanisms and treatment perspectives. Sports Med. 2010;40(7):641–656.
[23] Kraus VB, Burnett B, Coindreau J, et al. Application of biomarkers in osteoarthritis: current status and future directions. Osteoarthritis Cartilage. 2015;23(5):686–697.
[24] Filardo G, Previtali D, Napoli F, et al. Platelet-rich plasma injections for knee osteoarthritis: a meta-analysis of randomized controlled trials. Knee Surg Sports Traumatol Arthrosc. 2021;29(6):1904–1917.
[25] Yang F, Chen Y, Lu Z, et al. Treatment of knee osteoarthritis with acupuncture combined with Chinese herbal medicine: a systematic review and meta-analysis. Ann Palliat Med. 2021;10(11):11430–11444.
[26] Mavrommatis CI, Argyra E, Vadalouca A, et al. Traditional Chinese medicine in patients with osteoarthritis of the knee: a review of acupuncture and herbal therapies. Evid Based Complement Alternat Med. 2012;2012:429813.
[27] Bleakley CM, Glasgow P, MacAuley DC. Cryotherapy in the management of acute soft tissue injury: a systematic review.Am J Sports Med. 2012;40(1):207–216.
[28] Knoop J, Dekker J, van der Leeden M, et al. Knee joint stabilization therapy in patients with osteoarthritis and knee instability: a randomized clinical trial. Osteoarthritis Cartilage. 2013;21(8):1025–1034.
[29] Brosseau L, Wells GA, Tugwell P, et al. Ottawa panel evidence-based clinical practice guidelines for therapeutic ultrasound in the management of knee osteoarthritis. Phys Ther. 2003;83(9):712–731.
[30] Bannuru RR, Osani MC, Vaysbrot EE, et al. OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis. Osteoarthritis Cartilage. 2019;27(11):1578–1589.
[31] Pascual E, Sivera F. Crystal-induced arthritis: an update. Curr Opin Rheumatol. 2009;21(2):124–130.