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Review Article

Lower Back Pain Related to Sacrum- *A Short Review on Recent Findings*

Amitav Nayak[1], Bhagyalaxmi Jena[2], Sushree Swarupa Patra[3], Priyabrata Dash[4], Nihar Ranjan Mohanty[5], Dwarikanath Rout[6*]

[1]Senior Physiotherapist, KIMS School of Physiotherapy, KIMS, KIIT-DU, Bhubaneswar, Odisha
[2]Physiotherapist, KIMS School of Physiotherapy, KIMS, KIIT-DU, Bhubaneswar, Odisha
[3]Chief Physiotherapist, Kabita Physiotherapy and Sports Injury Rehab Centre, Bhubaneswar, Odisha
[4]Associate Professor cum Principal (I/C), KIMS School of Physiotherapy, KIMS, KIIT-DU, Bhubaneswar, Odisha
[5]Associate Professor, KIMS School of Physiotherapy, KIMS, KIIT-DU, Bhubaneswar, Odisha
[6]Assistant Professor, KIMS School of Physiotherapy, KIMS, KIIT-DU, Bhubaneswar, Odisha

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Abstract: Low back pain (LBP) is a pervasive health issue, affecting millions globally and leading to significant disability and healthcare costs. A crucial but often underappreciated aspect of LBP is its relationship to the sacrum, a large, triangular bone at the base of the spine, forming the posterior part of the pelvic girdle. The sacrum's role in load distribution and movement makes it a key player in both the onset and perpetuation of LBP. This review aims to consolidate current knowledge on sacral-related low back pain, discussing its etiology, clinical presentation, diagnostic strategies, and management options. By synthesizing recent research and clinical insights, the review seeks to provide a comprehensive resource for healthcare professionals and researchers. The review highlights the multifactorial nature of sacral-related LBP, encompassing biomechanical, inflammatory, and degenerative causes. Diagnostic advancements, particularly in imaging techniques, have enhanced the ability to identify sacral involvement in LBP. Treatment approaches range from conservative management to advanced surgical interventions, with emerging therapies showing promise in improving patient outcomes.

Keywords: Lower Back Pain, Sacrum, SI Joint, Spine, Rehabilitation.

INTRODUCTION

Low back pain (LBP) is defined as pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal folds, with or without leg pain. It is a leading cause of disability worldwide, affecting up to 80% of adults at some point in their lives (Hoy *et al.*, 2014). The socioeconomic burden of LBP is immense, with significant costs associated with healthcare utilization, lost productivity, and disability compensation. LBP can arise from a variety of anatomical structures including muscles, ligaments, nerves, intervertebral discs, and bones. Among these, the sacrum plays a critical role in the stability and function of the lower spine and pelvis. It acts as a keystone, distributing loads from the upper body to the lower extremities through the sacroiliac (SI) joints (Vleeming *et al.*, 2012). Dysfunction or pathology in the sacrum or SI joints can lead to significant pain and disability, contributing to the complexity of LBP. The primary objectives of this review are to provide a comprehensive overview of the anatomy and physiology of the sacrum and its role in LBP, to explore the etiological factors contributing to sacral-related LBP, to discuss the clinical presentation and diagnostic approaches for sacral-related LBP, to review current and emerging management strategies, including conservative, pharmacological, and surgical treatments, and to identify gaps in current research and suggest future directions for study.

Anatomy and Physiology of the Sacrum

The sacrum is a large, triangular bone at the base of the spine, composed of five fused vertebrae (S1-S5). It articulates with the lumbar spine at its superior end and with the coccyx at its inferior end. The sacrum forms the posterior part of the pelvic girdle, connecting with the ilium bones of the pelvis at the SI joints (Standring, 2016). The sacrum serves as a critical structural component of the vertebral column, providing stability and support. It helps to distribute the weight of the upper body to the pelvis and lower extremities. The sacral curvature also contributes to the overall alignment and balance of the spine (White & Panjabi, 2010). The

***Corresponding Author:** Dwarikanath Rout
Assistant Professor, KIMS School of Physiotherapy, KIMS, KIIT-DU, Bhubaneswar, Odisha

sacroiliac joints are synovial joints that connect the sacrum to the ilium bones of the pelvis. These joints play a crucial role in load transfer between the spine and lower extremities. They allow limited movement, primarily in the form of slight gliding and rotation, to accommodate changes in posture and locomotion (Pettine *et al*., 2017). The anatomy of the sacrum is complex and includes various structures such as the sacral foramina, which allow for the passage of sacral nerves and blood vessels. Additionally, the sacrum serves as an attachment site for several muscles and ligaments that are integral to the function and stability of the pelvis and lower back.

The sacrum's role in the human body extends beyond structural support. It acts as a central hub in the biomechanical network that includes the spine, pelvis, and lower limbs. The sacral promontory, the most anterior part of the sacrum, articulates with the last lumbar vertebra (L5), forming the lumbosacral joint. This joint is crucial for maintaining the angle between the lumbar spine and the pelvis, which is vital for upright posture and bipedal locomotion. Moreover, the sacrum's articulation with the ilium bones forms the sacroiliac joints, which are among the strongest joints in the body. These joints are stabilized by a network of ligaments, including the anterior and posterior sacroiliac ligaments, interosseous ligaments, and the iliolumbar ligaments. This ligamentous support is essential for transferring the weight of the upper body to the lower limbs and for absorbing the mechanical stresses that occur during movement.

The sacrum also plays a pivotal role in the neuromuscular system. The sacral plexus, a network of nerves that originates from the sacral spinal nerves, innervates the muscles and skin of the pelvis, perineum, and lower limbs. This plexus gives rise to important nerves such as the sciatic nerve, which is the largest nerve in the human body and is responsible for motor and sensory functions of the lower extremities. The involvement of the sacrum in such a broad range of physiological functions underscores its importance in both health and disease.

Etiology and Risk Factors

Sacral-related low back pain can arise from a variety of causes including trauma, degenerative changes, and inflammatory conditions. Trauma and injuries such as fractures, dislocations, and ligament injuries involving the sacrum and SI joints can lead to acute or chronic pain. These injuries are often the result of falls, motor vehicle accidents, or sports-related activities (Buchowski *et al*., 2008). Degenerative changes, such as osteoarthritis and degenerative disc disease, can affect the sacrum and SI joints, leading to pain and dysfunction (Kepler *et al*., 2013). Inflammatory conditions such as sacroiliitis and ankylosing spondylitis can cause significant pain and stiffness in the sacral region (Maksymowych, 2010). Risk factors for sacral-related low back pain include age, gender, occupation, and lifestyle. The prevalence of sacral-related LBP increases with age due to degenerative changes and decreased bone density (Wang *et al*., 2004). Females are more likely to experience sacral-related LBP, potentially due to hormonal influences and biomechanical differences (Hartvigsen *et al*., 2013). Jobs involving heavy lifting, prolonged sitting, or repetitive movements can increase the risk of sacral-related LBP (Hildebrandt *et al*., 1997). A sedentary lifestyle, poor posture, and obesity are significant risk factors for developing sacral-related LBP (Shiri *et al*., 2010). Certain genetic factors may predispose individuals to sacral-related LBP. Studies have identified genetic markers associated with an increased risk of developing conditions like ankylosing spondylitis and degenerative disc disease (Brown *et al*., 2002).

The etiology of sacral-related LBP is multifactorial and involves an interplay between mechanical, inflammatory, and degenerative processes. Mechanical factors include abnormal biomechanics, muscle imbalances, and postural deviations that place excessive stress on the sacrum and SI joints. Inflammatory factors involve autoimmune conditions such as ankylosing spondylitis, which can cause chronic inflammation and structural damage to the sacroiliac joints. Degenerative factors include age-related changes such as osteoarthritis, which can lead to the breakdown of cartilage and the formation of bone spurs that irritate surrounding tissues. Additionally, metabolic disorders such as osteoporosis can predispose individuals to sacral fractures and subsequent LBP.

Occupational factors play a significant role in the development of sacral-related LBP. Workers in occupations that involve heavy lifting, repetitive bending, and prolonged sitting are at increased risk. For example, truck drivers and office workers who spend long hours sitting are prone to developing sacral pain due to sustained pressure on the sacrum and poor posture. Furthermore, athletes engaged in high-impact sports such as gymnastics, football, and weightlifting are at risk of sacral injuries due to the high mechanical demands placed on their bodies.

Lifestyle factors such as physical inactivity, obesity, and smoking also contribute to the risk of developing sacral-related LBP. Physical inactivity leads to muscle weakness and poor flexibility, which can alter the biomechanics of the sacrum and SI joints. Obesity increases the mechanical load on the lower back and sacrum, leading to accelerated wear and tear of the joints. Smoking has been associated with impaired blood flow and reduced healing capacity of tissues, which can exacerbate degenerative changes in the sacrum and SI joints.

Genetic predispositions play a crucial role in the susceptibility to sacral-related LBP. Genetic studies have identified several genes associated with an increased risk

of developing conditions such as ankylosing spondylitis and degenerative disc disease. For instance, the HLA-B27 gene has been strongly linked to ankylosing spondylitis, a condition characterized by chronic inflammation of the sacroiliac joints and spine. Individuals with a family history of these conditions are at higher risk of developing sacral-related LBP.

CLINICAL PRESENTATION

Sacral-related low back pain can present with a variety of symptoms, making diagnosis and treatment a complex process. Patients may experience acute or chronic pain. Acute pain is typically sharp and localized, whereas chronic pain may be dull and diffuse (Deyo & Weinstein, 2001). Pain from the sacrum can radiate to the buttocks, hips, and lower extremities, often mimicking other conditions like sciatica (Schwarzer *et al.*, 1995). In addition to pain, patients may report stiffness, limited range of motion, and difficulty with activities of daily living.

Acute sacral-related LBP often results from traumatic events such as falls, sports injuries, or motor vehicle accidents. Patients typically report sudden onset of severe pain localized to the sacral region, often accompanied by muscle spasms and limited mobility. On physical examination, tenderness over the sacrum and sacroiliac joints is commonly noted. Radiographic imaging, including X-rays and CT scans, can help identify fractures or dislocations of the sacrum.

Chronic sacral-related LBP, on the other hand, develops gradually and is often associated with degenerative or inflammatory conditions. Patients with chronic pain may experience intermittent episodes of exacerbation and remission. The pain is often described as a deep, aching sensation that can radiate to the buttocks and thighs. Chronic sacral pain can significantly impact a patient's quality of life, leading to limitations in physical activities, sleep disturbances, and psychological distress.

The differential diagnosis for sacral-related LBP is broad and includes conditions such as disc herniation, spinal stenosis, and pelvic disorders. Herniated discs in the lumbar spine can cause symptoms similar to sacral-related LBP, necessitating careful differentiation through clinical and imaging studies (Frymoyer *et al.*, 1980). Spinal stenosis, characterized by the narrowing of the spinal canal, can compress nerves and lead to pain and neurological symptoms that overlap with sacral-related LBP (Amundsen *et al*., 2000). Pelvic disorders such as pelvic inflammatory disease, endometriosis, and pelvic fractures can present with similar symptoms, requiring comprehensive evaluation (Nezhat *et al*., 1994).

A thorough clinical assessment is essential for accurate diagnosis and effective management of sacral-related LBP. The assessment should include a detailed patient history, focusing on the onset, duration, and characteristics of pain, as well as any precipitating factors. Patients should be asked about any previous injuries, medical conditions, and lifestyle factors that may contribute to their pain. The presence of red flag symptoms such as unexplained weight loss, fever, or neurological deficits should be evaluated to rule out serious underlying conditions such as infections or malignancies.

Physical examination techniques such as palpation and provocation tests are essential in diagnosing sacral-related LBP. Palpating the sacral region and SI joints can help identify areas of tenderness and inflammation (Laslett *et al*., 2003). Provocation tests, such as the FABER (Flexion, Abduction, and External Rotation) test and Gaenslen's test, can help diagnose sacroiliac joint dysfunction (Laslett *et al*., 2005). The FABER test involves placing the patient in a supine position, with one leg flexed and the foot resting on the opposite knee. Gentle downward pressure is applied to the knee, and the test is considered positive if it elicits pain in the sacroiliac joint. Gaenslen's test involves extending one leg off the examination table while flexing the opposite knee toward the chest. Pain in the sacroiliac joint during this maneuver suggests sacroiliac joint dysfunction.

Imaging studies are a critical component of the diagnostic process for sacral-related LBP. X-rays are often the first imaging modality used to rule out fractures and structural abnormalities of the sacrum (Resnick, 2002). Magnetic resonance imaging (MRI) provides detailed images of soft tissues, including discs, ligaments, and nerves, helping to identify conditions like sacroiliitis and disc herniation (Modic *et al*., 1986). Computed tomography (CT) offers high-resolution images of bone structures, useful for detecting fractures and degenerative changes (Lee *et al*., 2013). Bone scans can detect bone abnormalities and inflammation, such as sacroiliitis (Donaldson *et al*., 1978). Ultrasound is useful for evaluating soft tissue injuries and guiding injections in the sacral region (Nacey *et al*., 2013). Sacroiliac joint injections can serve both diagnostic and therapeutic purposes. They involve injecting anesthetics or corticosteroids into the SI joint to confirm the source of pain and provide relief (Maigne *et al*., 1996).

DIAGNOSIS

The diagnosis of sacral-related low back pain involves a thorough clinical assessment and history taking. A detailed history, including the onset, duration, and characteristics of pain, as well as any precipitating factors, is crucial for diagnosing sacral-related LBP (Deyo & Diehl, 1986). Evaluating associated symptoms, such as radiating pain, numbness, and weakness, helps in identifying the underlying cause (Carragee, 1997). Physical examination techniques such as palpation and provocation tests are essential in diagnosing sacral-related LBP. Palpating the sacral region and SI joints can

help identify areas of tenderness and inflammation (Laslett *et al*., 2003). Provocation tests, such as the FABER (Flexion, Abduction, and External Rotation) test and Gaenslen's test, can help diagnose sacroiliac joint dysfunction (Laslett *et al*., 2005). Imaging studies are a critical component of the diagnostic process for sacral-related LBP. X-rays are often the first imaging modality used to rule out fractures and structural abnormalities of the sacrum (Resnick, 2002). Magnetic resonance imaging (MRI) provides detailed images of soft tissues, including discs, ligaments, and nerves, helping to identify conditions like sacroiliitis and disc herniation (Modic *et al*., 1986). Computed tomography (CT) offers high-resolution images of bone structures, useful for detecting fractures and degenerative changes (Lee *et al*., 2013). Bone scans can detect bone abnormalities and inflammation, such as sacroiliitis (Donaldson *et al*., 1978). Ultrasound is useful for evaluating soft tissue injuries and guiding injections in the sacral region (Nacey *et al*., 2013). Sacroiliac joint injections can serve both diagnostic and therapeutic purposes. They involve injecting anesthetics or corticosteroids into the SI joint to confirm the source of pain and provide relief (Maigne *et al*., 1996).

In addition to traditional imaging techniques, advanced imaging modalities such as functional MRI (fMRI) and positron emission tomography (PET) are being explored for their potential in diagnosing sacral-related LBP. These imaging techniques can provide insights into the functional and metabolic changes in the sacrum and surrounding tissues, aiding in the identification of subtle abnormalities that may not be visible on standard imaging. Furthermore, advancements in imaging technology, such as high-resolution MRI and three-dimensional CT, have improved the accuracy and specificity of diagnostic imaging for sacral-related LBP.

Diagnostic injections are a valuable tool in the assessment of sacral-related LBP. These injections involve the use of local anesthetics and corticosteroids to temporarily relieve pain and inflammation in the sacroiliac joint. If the patient experiences significant pain relief following the injection, it suggests that the sacroiliac joint is the primary source of pain. This information can guide treatment decisions and help confirm the diagnosis of sacroiliac joint dysfunction. Diagnostic injections can also be used to differentiate sacral-related LBP from other conditions such as lumbar disc herniation or facet joint syndrome.

Electrodiagnostic studies, including electromyography (EMG) and nerve conduction studies (NCS), are sometimes used to evaluate nerve function and identify potential nerve involvement in sacral-related LBP. EMG measures the electrical activity of muscles and can help detect abnormalities such as muscle weakness or denervation. NCS assess the speed and strength of nerve signals, which can help identify nerve compression or damage. These studies are particularly useful in cases where patients present with radiating pain, numbness, or weakness, as they can help differentiate between sacral-related LBP and other conditions such as lumbar radiculopathy.

Laboratory tests may be indicated in certain cases to rule out systemic conditions that can contribute to sacral-related LBP. Blood tests, such as complete blood count (CBC), erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP), can help identify underlying inflammatory or infectious processes. For patients with suspected ankylosing spondylitis or other inflammatory conditions, genetic testing for HLA-B27 may be performed. Elevated levels of ESR and CRP, along with the presence of HLA-B27, can support the diagnosis of ankylosing spondylitis.

MANAGEMENT AND TREATMENT

The management and treatment of sacral-related low back pain involve a multifaceted approach, including conservative management, pharmacological treatments, interventional procedures, and surgical options. Conservative management, such as physical therapy and exercise, is often the first line of treatment for sacral-related LBP. Specific exercises, including stretching, strengthening, and stabilization exercises, can help alleviate pain and improve function (McGill, 2007). Physical therapy approaches, such as manual therapy, massage, and heat/cold therapy, can be effective in managing pain and improving function (Furlan *et al*., 2015).

Physical therapy plays a central role in the management of sacral-related LBP. A comprehensive physical therapy program typically includes a combination of therapeutic exercises, manual therapy, and patient education. Therapeutic exercises aim to improve flexibility, strength, and stability of the muscles supporting the sacrum and lower back. Stretching exercises focus on lengthening tight muscles, such as the hamstrings, hip flexors, and piriformis, which can contribute to sacral pain. Strengthening exercises target the core muscles, including the abdominal, back, and pelvic floor muscles, to enhance spinal stability and support. Stabilization exercises involve maintaining proper posture and body mechanics during various activities to prevent excessive stress on the sacrum and SI joints.

Manual therapy techniques, such as joint mobilization and manipulation, can help alleviate pain and improve joint mobility. These techniques involve applying controlled forces to the sacroiliac joint and surrounding structures to restore normal joint function and reduce pain. Massage therapy can also be beneficial in relieving muscle tension and promoting relaxation. Heat and cold therapy are commonly used to manage acute pain and inflammation. Heat therapy, such as warm compresses or heating pads, helps relax muscles and increase blood flow to the affected area. Cold therapy,

such as ice packs, helps reduce swelling and numb the area, providing temporary pain relief.

Patient education is a crucial component of physical therapy. Educating patients about proper body mechanics, posture, and ergonomics can help prevent recurrent episodes of sacral-related LBP. Patients should be advised to avoid activities that place excessive stress on the sacrum, such as heavy lifting, prolonged sitting, or repetitive bending. They should also be encouraged to engage in regular physical activity, maintain a healthy weight, and practice good posture to reduce the risk of sacral pain.

Pharmacological treatments commonly used to manage sacral-related LBP include nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and muscle relaxants (Chou *et al*., 2007). These medications can help reduce pain and inflammation, although they may have side effects that need to be monitored. NSAIDs, such as ibuprofen and naproxen, are often the first-line medications for managing mild to moderate pain and inflammation. Acetaminophen is an alternative for patients who cannot tolerate NSAIDs or have contraindications. Muscle relaxants, such as cyclobenzaprine and baclofen, can be used to relieve muscle spasms and improve mobility.

For patients with chronic or severe pain, opioid analgesics may be considered. However, opioids should be used with caution due to the risk of addiction and other adverse effects. Long-term use of opioids is generally discouraged, and these medications should be reserved for patients who do not respond to other treatments. Adjuvant medications, such as antidepressants and anticonvulsants, can also be used to manage neuropathic pain associated with sacral-related LBP. Antidepressants, such as amitriptyline and duloxetine, have been shown to be effective in reducing chronic pain and improving mood. Anticonvulsants, such as gabapentin and pregabalin, can help alleviate nerve pain and improve sleep.

Interventional procedures, such as corticosteroid injections and radiofrequency ablation, can provide significant pain relief for patients with sacral-related LBP. Corticosteroid injections into the sacroiliac joint can help reduce inflammation and pain (Vallejo *et al.*, 2006). These injections are typically performed under fluoroscopic or ultrasound guidance to ensure accurate placement of the medication. The effects of corticosteroid injections can last for several weeks to months, providing temporary relief for patients with sacroiliac joint dysfunction. Radiofrequency ablation involves using radiofrequency energy to disrupt nerve function and reduce pain originating from the sacroiliac joint (Burnham *et al.*, 2009). This procedure targets the sensory nerves that transmit pain signals from the sacroiliac joint to the brain. By applying heat generated by radiofrequency waves, the nerves are temporarily disabled, reducing pain perception. Radiofrequency ablation can provide long-lasting pain relief for several months to a year.

Surgical options for sacral-related LBP are considered when conservative and interventional treatments fail to provide adequate relief. Surgical options include sacroiliac joint fusion and decompression surgeries. Sacroiliac joint fusion involves stabilizing the joint by fusing the sacrum and ilium bones, which can help reduce pain and improve function (Duhon *et al.*, 2016). This procedure is typically performed using minimally invasive techniques, such as percutaneous screw fixation or the insertion of titanium implants. Decompression surgeries are performed to relieve pressure on the nerves and spinal cord caused by conditions such as spinal stenosis. The success rates of these surgeries vary, and potential complications include infection, hardware failure, and nonunion (Polly *et al.*, 2016).

Sacroiliac joint fusion is considered for patients with chronic sacroiliac joint dysfunction that does not respond to other treatments. The goal of the procedure is to eliminate movement at the sacroiliac joint, thereby reducing pain and improving stability. Minimally invasive techniques, such as percutaneous screw fixation, involve the insertion of screws or rods through small incisions to fuse the joint. These techniques have the advantage of reduced surgical trauma, shorter recovery times, and lower complication rates compared to traditional open surgery. The success rates of sacroiliac joint fusion vary, with reported pain relief rates ranging from 50% to 80%. However, potential complications include infection, nerve injury, and nonunion, where the bones fail to fuse properly.

Decompression surgeries are performed to relieve pressure on the nerves and spinal cord caused by conditions such as spinal stenosis or herniated discs. The goal of these surgeries is to alleviate pain and improve neurological function by removing the structures that compress the nerves. Common decompression procedures include laminectomy, discectomy, and foraminotomy. Laminectomy involves the removal of a portion of the vertebral bone called the lamina to create more space for the spinal cord and nerves. Discectomy involves the removal of a herniated or damaged disc that is compressing the nerves. Foraminotomy involves the enlargement of the openings (foramina) where the nerves exit the spine to relieve pressure. The success rates of decompression surgeries vary, with reported outcomes ranging from 60% to 90%. Potential complications include infection, nerve injury, and recurrence of symptoms.

REHABILITATION AND PREVENTION

Rehabilitation and prevention strategies play a crucial role in managing sacral-related low back pain and preventing recurrence. Physiotherapy is an essential

component of rehabilitation, focusing on tailored exercise programs that improve flexibility, strength, and stabilization (Koes *et al*., 2006). Ergonomic adjustments in the workplace and at home, such as improving chair support and workstation setup, can help prevent and manage sacral-related LBP (Amick *et al*., 2003). Adopting a healthy lifestyle, including regular physical activity, maintaining a healthy weight, and avoiding smoking, can reduce the risk of sacral-related LBP (Hagen *et al*., 2005). Implementing preventive strategies, such as educational programs and early intervention for at-risk populations, can help mitigate the incidence of sacral-related LBP (Linton & Van Tulder, 2001).

A comprehensive rehabilitation program for sacral-related LBP typically includes a combination of therapeutic exercises, manual therapy, and patient education. Therapeutic exercises aim to improve flexibility, strength, and stability of the muscles supporting the sacrum and lower back. Stretching exercises focus on lengthening tight muscles, such as the hamstrings, hip flexors, and piriformis, which can contribute to sacral pain. Strengthening exercises target the core muscles, including the abdominal, back, and pelvic floor muscles, to enhance spinal stability and support. Stabilization exercises involve maintaining proper posture and body mechanics during various activities to prevent excessive stress on the sacrum and SI joints.

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Patient education is a crucial component of rehabilitation and prevention. Educating patients about proper body mechanics, posture, and ergonomics can help prevent recurrent episodes of sacral-related LBP. Patients should be advised to avoid activities that place excessive stress on the sacrum, such as heavy lifting, prolonged sitting, or repetitive bending. They should also be encouraged to engage in regular physical activity, maintain a healthy weight, and practice good posture to reduce the risk of sacral pain.

Ergonomic adjustments in the workplace and at home can help prevent and manage sacral-related LBP. Improving chair support, workstation setup, and posture can reduce the mechanical stress on the sacrum and lower back. For example, using an ergonomic chair with proper lumbar support can help maintain the natural curvature of the spine and reduce the risk of sacral pain. Adjusting the height of the desk and computer monitor to eye level can help prevent forward head posture and neck strain. Encouraging regular breaks and stretching exercises during prolonged sitting can also help alleviate pressure on the sacrum and lower back.

Adopting a healthy lifestyle is essential for preventing sacral-related LBP. Regular physical activity, such as walking, swimming, or yoga, can help maintain muscle strength and flexibility, reducing the risk of sacral pain. Maintaining a healthy weight can reduce the mechanical load on the lower back and sacrum, preventing wear and tear on the joints. Avoiding smoking is also important, as smoking has been associated with impaired blood flow and reduced healing capacity of tissues, which can exacerbate degenerative changes in the sacrum and SI joints.

Implementing preventive strategies, such as educational programs and early intervention for at-risk populations, can help mitigate the incidence of sacral-related LBP. Educational programs can raise awareness about the risk factors and preventive measures for sacral pain, empowering individuals to take proactive steps to protect their back

Health Early intervention for individuals with risk factors, such as physical inactivity, obesity, or occupational hazards, can help prevent the onset of sacral pain and reduce the burden of chronic LBP.

CURRENT RESEARCH AND FUTURE DIRECTIONS

Recent research has provided new insights into the biomechanical and neurophysiological aspects of sacral-related LBP, enhancing diagnostic and therapeutic approaches (Vleeming *et al*., 2012). Emerging treatments, such as biologics, regenerative therapies, and advanced imaging techniques, show promise in improving the management of sacral-related LBP (Vad *et al*., 2002). However, there are still significant gaps in understanding the precise mechanisms and optimal treatment strategies for sacral-related LBP. Future research should focus on large-scale, randomized controlled trials and the development of personalized medicine approaches (Foster *et al*., 2018).

Biomechanical studies have advanced our understanding of the forces and movements that contribute to sacral pain. These studies have demonstrated the importance of pelvic alignment, muscle coordination, and load distribution in maintaining sacral stability. For example, research has shown that abnormal pelvic tilt and asymmetrical loading can increase stress on the sacroiliac joints, leading to pain and dysfunction. Biomechanical models and simulations have provided valuable insights into the effects of various interventions, such as exercises and

orthotics, on sacral mechanics. These findings have informed the development of targeted rehabilitation programs and preventive measures for sacral-related LBP.

Neurophysiological research has shed light on the role of the nervous system in sacral pain. Studies have demonstrated that the sacroiliac joints and surrounding tissues are richly innervated with sensory nerves, which can become sensitized and contribute to chronic pain. Neuroimaging studies, such as functional MRI (fMRI), have revealed changes in brain activity associated with chronic sacral pain, highlighting the complex interplay between peripheral and central pain mechanisms. Advances in neurophysiology have also led to the development of novel treatments, such as neuromodulation techniques, that target the nervous system to alleviate sacral pain.

Emerging treatments for sacral-related LBP include biologics and regenerative therapies. Biologic treatments, such as platelet-rich plasma (PRP) and stem cell therapy, aim to promote healing and regeneration of damaged tissues. PRP involves injecting a concentrated solution of platelets, which contain growth factors and cytokines, into the affected area to stimulate tissue repair. Stem cell therapy involves injecting stem cells, which have the potential to differentiate into various cell types, to regenerate damaged tissues and reduce inflammation. Preliminary studies have shown promising results for these treatments in reducing pain and improving function in patients with sacral-related LBP. However, further research is needed to establish their long-term efficacy and safety.

Advanced imaging techniques, such as high-resolution MRI and three-dimensional CT, have improved the accuracy and specificity of diagnostic imaging for sacral-related LBP. These techniques provide detailed images of the sacrum and surrounding structures, allowing for better identification of subtle abnormalities and accurate assessment of joint alignment and integrity. Functional imaging techniques, such as fMRI and PET, are being explored for their potential to assess the metabolic and functional changes in the sacrum and surrounding tissues. These advanced imaging modalities can provide valuable information for diagnosis, treatment planning, and monitoring of therapeutic outcomes.

Future research directions should focus on large-scale, randomized controlled trials to evaluate the efficacy and safety of emerging treatments for sacral-related LBP. These trials should include diverse patient populations and long-term follow-up to assess the durability of treatment effects. Additionally, research should explore the potential of personalized medicine approaches, which tailor treatments based on individual patient characteristics, such as genetic profiles, biomechanical factors, and pain phenotypes. Personalized medicine has the potential to improve treatment outcomes by addressing the underlying mechanisms and individual variability in sacral-related LBP.

Collaboration between researchers, clinicians, and patients is essential for advancing our understanding and management of sacral-related LBP. Multidisciplinary research teams that include experts in biomechanics, neurophysiology, imaging, and clinical practice can provide comprehensive insights into the complex nature of sacral pain. Engaging patients in research through patient-centered approaches and participatory research methods can ensure that the findings are relevant and applicable to clinical practice.

CONCLUSION

This review highlights the complexity of sacral-related LBP, encompassing a range of etiological factors, diagnostic challenges, and treatment options. Understanding the sacrum's role in LBP is crucial for effective management and improved patient outcomes. Clinicians should adopt a comprehensive approach to diagnosing and treating sacral-related LBP, considering the multifactorial nature of the condition and individual patient needs. Continued research into the underlying mechanisms and innovative treatments for sacral-related LBP is essential. Clinicians should stay updated with the latest evidence-based practices and consider multidisciplinary approaches for optimal patient care.

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