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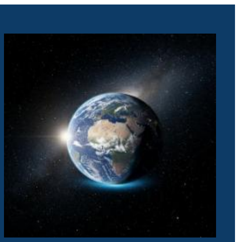

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Etiology, Clinical Management, and Prevention of Mechanical Lumbar Spine Dysfunction in Rowing Athletes: A Narrative Review

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Abstract

Background. Rowing is a demanding endurance sport that causes extreme mechanical loading of the lumbar spine. Consequently, mechanical lumbar spine dysfunction is a highly prevalent injury, that leads to training interruptions and threatens athletic performance.

Aim. This review systematically synthesizes literature regarding the risk factors, biomechanics, structural alterations, prevention, and management of lumbar spine overload in rowers. Highlighting that imaging findings alone are insufficient for clinical decision-making.

Material and methods. A comprehensive database search was conducted using scientific databases, including PubMed and Google Scholar. Data from reviews, meta-analyses, observational studies, RCTs, electromyography analyses, and qualitative research on lumbar dysfunction in rowers were synthesized.

Results. Prolonged stationary ergometer use and a previous injury history are the strongest injury predictors. Biomechanically, the drive phase is the most critical segment for symptom exacerbation. EMG analyses demonstrate that rowers with lumbar pain have excessive back muscle activation. This indicates compensatory overactivation rather than baseline weakness. MRI studies reveal that structural spine alterations even in asymptomatic athletes. Psychosocially, athletes frequently normalize severe back pain, fostering a culture of concealment that exacerbates chronic tissue damage. Pre-participation screening effectively identifies at-risk rowers using the Functional Movement Screen, as well as plank and Sorensen tests to evaluate core endurance.

Conclusions. Lumbar dysfunction in rowers is a multifactorial condition demanding a shift from a strictly biomedical focus to a comprehensive biopsychosocial model. Prevention requires regular functional screening, optimizing technique over sheer force, strict ergometer load management, and educating athletes to encourage early injury reporting.

Keywords: rowing, low back pain, biomechanics, injury prevention, rowing ergometer.

1. Introduction

Rowing is a demanding endurance sport that requires coordinated movement of the upper and lower limbs to propel the boat (S. L. Gonzalez et al., 2018). Due to the cyclical, repetitive nature of the discipline, an elite athlete can perform thousands of strokes in one training session. This places tremendous physiological and biomechanical stress on the musculoskeletal system, particularly the lower back (T. M. Hosea and J. A. Hannafin, 2012; H. Ma et al., 2024).

The effectiveness of the stroke relies on coordinated loading of lower limbs, trunk and upper extremities. This maximizes power and spreads forces to prevent excessive strain (A. Baudouin and D. Hawkins, 2002; S. Arumugam et al., 2020). However, the repetitive shifts from compression to powerful extension expose the spine to extreme vulnerability, forcing it to act as a braced cantilever that frequently leads to symptom exacerbation and cumulative microtrauma (T. M. Hosea and J. A. Hannafin, 2012; H. Ma et al., 2024).

Rowing athletes often experience pain and injuries. This may impair their training and competitive performance and even precipitate the cessation of their athletic careers (V. Athy et al., 2023). Despite the high prevalence of mechanical lumbar spine dysfunction among rowers, current research mainly focuses on post-injury interventions with limited attention given to pre-injury warning signals and comprehensive biomechanical mechanisms (X. Ze et al., 2025).

The aim of this narrative review is to systematically synthesize current evidence on the primary risk factors, biomechanical mechanisms, structural alterations, prevention strategies, and clinical management of mechanical lumbar spine dysfunction in rowers (X. Ze et al., 2025). By advocating for a multimodal approach, the review highlights the importance of identifying modifiable impairments to reduce the long-term impact of lumbar injuries on athletes (M.B. Casey et al., 2022).

2. Research Materials and Methods

To conduct this narrative review, a comprehensive literature search was conducted across primary scientific databases, including PubMed and Google Scholar. The search targeted peer-reviewed articles published predominantly between 2000 and 2026 to ensure the inclusion of the most recent epidemiological, biomechanical, and clinical data. The selected literature primarily encompassed systematic reviews, meta-analyses, observational studies, randomized controlled trials (RCTs), electromyography (EMG) analyses, and qualitative research. Keywords utilized in the search strategy included: “rowing”, “low back pain”, “risk factors”, “biomechanics”, and “ergometer”. Articles not published in English, non-peer-reviewed grey literature, single case reports lacking a wider population context, as well as studies focusing on specific low back pain caused by systemic diseases or acute traumatic fractures were excluded from the synthesis.

3. Biomechanics and Kinematics of the Rowing Stroke

The rowing stroke is a continuous, repetitive motion that is traditionally divided into four distinct phases: the catch, the drive, the finish, and the recovery (T. M. Hosea and J. A. Hannafin, 2012). Proper movement sequencing and coordination are critical not only for optimizing propulsive power but also for minimizing the risk of musculoskeletal injuries (A. Baudouin and D. Hawkins, 2002).

3.1. Phases of the Rowing Stroke

- **The "catch" phase:** The catch marks the critical initiation of the propulsive movement when the oar blade enters the water vertically and is anchored (E. Baumann and M. Schmid, 2024). At this exact moment, the athlete's body is in a position of maximal compression: the hips are fully flexed, the knees reach a maximum flexion angle of approximately 110° to 120°, the arms are fully extended forward, and the lumbar spine is held in about 30 degrees of flexion (T. Hosea and J. Hannafin, 2012). This highly compressed posture stores significant potential energy in the legs, back, and arms, requiring precise core co-activation before the propulsive force is applied (T. Hosea and J. Hannafin, 2012).
- **The "drive" phase:** Immediately following the catch, the drive phase begins as the legs push forcefully against the foot stretcher to accelerate the boat (I. Engstrom et al., 2023). The rectus femoris initiates power, followed closely by the gluteus maximus and hamstrings, which control knee and hip extension while stabilizing the pelvis (T. Hosea and

J. Hannafin, 2012). Crucially, during this phase, the back, shoulders, and arms act as a braced cantilever, transferring the massive forces generated by the legs directly to the oar (T. Vieira et al., 2017). As the drive progresses, the spine transitions dynamically from 30 degrees of flexion to approximately 30 degrees of extension, with the paraspinal muscles firing heavily to stabilize the spine against extreme compressive and shear loads (T. Hosea and J. Hannafin, 2012). The effectiveness of this phase depends heavily on the sequential, coordinated loading of the legs, back, and arms, which maximizes propulsive power while distributing peak segmental forces appropriately to avoid excessive strain (A. Baudouin and D. Hawkins, 2002).

- **The "finish" (or release) phase:** The drive phase concludes at the finish, where the oar blade is extracted from the water and feathered (rotated parallel to the water's surface) (T. Agius et al., 2023). In this posture, the rower's legs are fully extended, the trunk is slightly reclined (extended), and the elbows are fully flexed, bringing the hands close to the body at waist height (V. Giustino et al., 2022). While the major propulsive leg muscles generate minimal activity at this stage, the rectus abdominis and external oblique muscles fire intensely to decelerate the trunk and stabilize the extended body posture (T. Hosea and J. Hannafin, 2012).
- **The "recovery" phase:** The recovery is the final stage, allowing the athlete to return to the catch position while the oar remains out of the water (E. Baumann and M. Schmid, 2024). The movement begins sequentially with the arms extending away from the body, followed by the forward flexion of the hips and spine (L. Heyneke and A. Green, 2021). Once the hands pass the knees, the hamstrings fire submaximally to flex the knees and slide the seat forward (T. Hosea and J. Hannafin, 2012). During this phase, paraspinal muscle activity is almost non-existent, reflecting a brief period of unloading for the lumbar discs before the blade is squared for the next stroke (T. Hosea and J. Hannafin, 2012).

3.2. Additional Kinematic Variables

Rowing kinematics and subsequent spinal loading are heavily influenced by the discipline and equipment setup. Sweep rowing introduces significant asymmetry, requiring lateral flexion and rotation, increasing torsional stress on the back, compared to symmetrical sculling (C. Benedikter et al., 2022; S. Arumugam et al., 2020). Equipment adjustments, such as modifying the height or angle of the foot-stretcher, primarily alter ankle kinematics and have minimal effects on the upper spine (I. Engstrom et al., 2023). Recent biomechanical research shows that modifying the oar blade angle (e.g., to a 5-degree angle) can alter hydrodynamics without significantly increasing the dangerous muscular activation of the erector spinae during the drive phase (B. van Trigt et al., 2026

4. Epidemiological Risk Factors: Training Volume, Ergometer Use, and Previous Injury

Rowing is a highly demanding endurance sport that requires enormous training volumes. Epidemiological studies estimate the overall incidence of low back pain (LBP) to be between 1.5 and 3.7 per 1000 hours of rowing training and competition, making the lumbar spine the most commonly injured anatomical site across all rowing populations (V. Athy et al., 2023; H. Ma et al., 2024). A particularly critical period for the onset and exacerbation of LBP is the winter training season. This period is associated with a significantly higher injury rate due to the transition from dynamic on-water rowing to heavy land-based conditioning, which includes heavy resistance training and extended indoor rowing sessions (V. Athy et al., 2023; C. Benedikter et al., 2022).

The stationary rowing ergometer is a fundamental conditioning tool, but its prolonged use is consistently identified as a major risk factor for lumbar spine dysfunction (R. Cardoso et al., 2024; V. Athy et al., 2023). Ergometer sessions longer than 30 minutes significantly increase the risk of LBP (T. M. Hosea and J. A. Hannafin, 2012). Unlike on-water rowing, the stationary ergometers eliminate the need for lateral balance, profoundly altering the athlete's sensory feedback and increasing mechanical stabilization demands on the passive structures of the spine (V. Athy et al., 2023). To reduce risk during winter training, athletes should use dynamic (floating-head) ergometers instead of traditional stationary (fixed-head) models. Biomechanical studies show that fixed-head designs require more mechanical work per stroke and longer stroke lengths, which increases cumulative strain on the lumbar spine.

While traditional beliefs often attribute LBP directly to sheer training volume or years of experience, a recent comprehensive meta-analysis has challenged this consensus. The study revealed that absolute training volume, body mass index (BMI), age, and the number of years rowing are not statistically significant independent risk factors (X. Ze et al., 2025). Instead, a previous history of low back pain is the most significant predictor of future lumbar injuries, with a 2.65 times higher risk of recurrence (X. Ze et al., 2025). This creates a chronic cycle of pain and cumulative tissue microtrauma, explaining why athletes with preexisting LBP are at a dramatically higher risk of further episodes (V. Athy et al., 2023; H. Ma et al., 2024).

The prevalence and severity of lumbar injuries also vary by age, sex, and competitive level. Although international elite rowers experience a high lifetime prevalence of LBP, national-level and amateur rowers are statistically more likely to sustain severe lumbar injuries resulting in significant training time loss of greater than five days (G. Verrall and A. Darcey, 2014). This difference is likely due to elite athletes benefiting from superior technical execution, professional load management and robust medical suport. In older demographics, such as international masters rowers, the lower back remains the most frequently injured anatomical site- accounting for over 32% of all injuries- though these older athletes primarily suffer from chronic, low-severity overuse injuries rather than acute, time-loss traumas (T. Smoljanović et al., 2018).

5. Biomechanical Risk Factors and Spinal Loading in Rowing

5.1. Compressive and Shear Forces during the Stroke Cycle

The repetitive motion of rowing exposes the lumbar spine to extreme compressive and anterior shear forces. During the "catch" and early "drive" phases, the spine functions essentially as a braced cantilever in a highly flexed position, typically reaching approximately 30 degrees of lumbar flexion (T. M. Hosea and J. A. Hannafin, 2012). This flexed posture is maintained for up to 70% of the stroke cycle, increasing the risk of mechanical overload to the intervertebral discs and posteriori passive structures (D. A. Reid and P. J. McNair, 2000). At the peak of the drive phase, compressive forces acting on the lower lumbar segments, specifically L4-L5 and L5-S1, can reach up to 6066 N in men and 5031 N in women (T. M. Hosea and J. A. Hannafin, 2012). This equates to roughly 4.6 to 7 times the athlete's body weight, often accompanied by anterior shear forces exceeding 700 to 800 N (F. L. Morris et al., 2000).

5.2. Symmetrical vs. Asymmetrical Loading: Sculling and Sweep Rowing

An essential consideration in injury etiology is the distinction between sweep rowing and sculling. While sculling involves a relatively symmetrical movement in the sagittal plane, sweep rowing introduces substantial asymmetrical loading (S. Arumugam et al., 2020). The sweep stroke requires continuous lumbar lateral flexion and axial rotation in addition to forward flexion, which dramatically increases torsional stress on the facet joints, joint capsules, and the outer annulus of the intervertebral discs (R. Schäfer et al., 2022). Consequently, rowers utilizing the sweep technique are exposed to more complex, multi-planar mechanical strain, which significantly increases the risk of chronic microtrauma and disc degeneration compared to their sculling counterparts (X. Ze et al., 2025).

5.3. Impact of Muscular Fatigue and Kinematic Compensation

Technique deterioration due to muscular fatigue during prolonged training sessions significantly alters spinal kinematics. Repetitive loading induces "viscoelastic creep" in the posterior passive soft tissues, which diminishes their stiffness and transfers a greater stabilization burden onto the active paraspinal musculature (D. A. Reid and P. J. McNair, 2000). Additionally, neuromuscular fatigue desensitizes mechanoreceptors in the spinal ligaments and delays trunk muscle reflexes, particularly during eccentric deceleration phases, which severely compromises dynamic spinal stability (R. Schäfer et al., 2022; I. A. Bernstein et al., 2002).

As fatigue increases, athletes often use greater lumbar flexion and execute longer stroke lengths, which raises mechanical strain on the lower back (H. A. Mackenzie et al., 2008). This compensation can also affect the cervical spine. As stroke rates increase, young rowers have been observed to exhibit increased compensatory neck extension to maintain visual focus (V. Giustino et al., 2022).

5.4. Training Environments: Stationary Ergometers vs. On-Water Rowing

While subtle adjustments such as foot-stretcher height or oar blade angles have been shown to have minimal direct impact on the upper spine or lumbopelvic rhythm (I. Engstrom et al., 2023; B. van Trigt et al., 2026), the training environment, practiculary the use of stationary ergometers is a critical factor. The rigid design of traditional stationary ergometers limits natural pelvic rotation and freedom of the pelvis, forcing rowers to compensate with increased lumbar flexion compared to the dynamic movement possible on the water (F. Wilson et al., 2013).

To systematically summarize how altered biomechanics disrupt the lumbar spine, the vulnerabilities of the stationary ergometer compared to on-water rowing are outlined in Table 1.

Table 1. Comparison between Stationary Ergometer and On-Water Rowing

Biomechanical Parametr	Stationary Ergometr	On-Water Rowing	Clinical Impact on Lumbar Spine
Lumbopelvic kinematics	Restricts natural pelvic ratation, forcing increased lumbar spine flexion at the catch phase.	Allows for natural lumbopelvic rythm and unrestricted pelvic rotation.	Chronically elevates compressice and shear forces, accelerating cumulative tissuse fatigue.
Stabilization Requirements	Lack of lateral balance requirements alters sensory feedback and spinal stabilization demands.	Requires continuous lateral balance and complex multidirectional body adjustments.	Altered feedback may compromise stability, making the spine more susceptible to acute strains.
Stroke length	Forces the athlete to execute significantly longer stroke lengths at the catch phase.	Stroke length is naturally regulated by the boat's movement and water resistance.	Longer stroke lengths stretch posterior structures, directly increasing mechanical strain.
Compressive & Shear Loading	Forces the athlete to perform significantly more work and higher mean forces per stroke due to machine rigidity	Forces are dissipated more efficiently by accelerating the boat's mass through the water.	Higher repetitive loads during sessions (>30 min) are a primary trigger for the development of LBP.
Neuromuscular Activation (EMG)	Promotes overactivation of the erector spinae muscles to overcome initial machine inertia.	Allows for natural, sequential loading of the legs, back, and arms, optimizing force transmission.	Excessive, continuous activation of back muscles accelerates fatigue and alters protection mechanisms.

Source: Own elaboration based on current literature.

5.5. Variations in Rowing Dynamics: Fixed-Seat vs. Sliding-Seat

Although modern rowing mainly uses sliding seats, traditional fixed-seat rowing immobilizes the pelvis, forcing athletes to use greater lumbar and thoracic flexion to complete the stroke. Clinical studies show that fixed-seat rowers have a similar incidence of lower back injuries as those using sliding seats, but significantly fewer knee injuries. This suggests that, despite different stroke mechanics, cumulative lumbar spine strain is a major concern in both disciplines (T. P. Agius et al., 2023)

6. Structural and Muscular Alterations: MRI and EMG Findings

The repetitive, high load flexion and extension cycles inherent to the rowing stroke result in a high incidence of structural and muscular alterations within the lumbopelvic region. Magnetic resonance imaging (MRI) studies have revealed an alarming prevalence of spinal abnormalities in this group. For example, imaging of adolescent rowers demonstrated that 95.2% of males and 78.9% of females exhibited positive findings for structural spinal anomalies, including disc herniations and degenerative changes (T. M. Hosea and J. A. Hannafin, 2012).

Advanced quantitative imaging using T2* mapping has further demonstrated that even entirely asymptomatic elite rowers possess significantly lower T2* values in their lumbar intervertebral discs compared to age-matched, non-rowing controls (C. Benedikter et al., 2022). These structural alterations are most frequently observed and most severe in the lower lumbar segments, particularly at the L4-L5 and L5-S1 levels. Lower T2* values strongly correlate with higher Pfirrmann grades and indicate early microstructural matrix degradation, a loss of tissue hydration, and reduced disc vitality (C. Benedikter et al., 2022). Importantly, the presence of advanced degenerative changes in pain-free athletes highlights a critical clinical discrepancy: abnormal MRI findings are common in the rowing population and do not dependably correlate with clinical manifestation of pain. Therefore, imaging alone is insufficient for diagnosing the exact source of symptoms (D. Fett et al., 2017; K. Trompeter et al., 2017).

Pathophysiological adaptations related to lumbar dysfunction extend beyond the passive intervertebral discs to involve the active paraspinal musculature Contrary to the traditional clinical assumption that low back pain results from localized muscle atrophy or baseline weakness, MRI morphometry of elite oarsmen revealed that rowers with a history of low back pain actually possess significantly larger cross-sectional areas of the posterior trunk muscles, specifically the multifidus and erector spinae, compared to their asymptomatic peers (A. H. McGregor et al., 2002). Furthermore, despite the asymmetric torsional demands of sweep rowing, no significant left-to-right muscular asymmetries were observed in these athletes, regardless of their preferred rowing side (A. H. McGregor et al., 2002). This hypertrophy suggests that lumbar dysfunction in elite rowers is not primarily driven by muscular weakness, but rather represents a chronic hypertrophic adaptation to extreme mechanical strain.

This structural hypertrophy is directly coupled with altered, maladaptive neuromuscular control. Surface electromyography (EMG) analyses demonstrate that rowers with low back pain exhibit a significantly higher activation of global trunk muscles, namely the thoracic erector spinae, lumbar erector spinae, and latissimus dorsi, compared to healthy controls during the critical drive phase (0-30% of the stroke cycle) at maximal effort (M. Yamashita et al., 2023). Because these global, superficial muscles are primarily responsible for producing substantial torque and balancing extrinsic burdens, their compensatory overactivation dramatically increases the compressive and shear stress placed on the spine (M. Yamashita et al., 2023; R. Schäfer et al., 2022). These findings suggest that mechanical lumbar dysfunction in rowers is characterized by a protective muscular spasm and a hyperactive feedforward compensation, reflecting central nervous system plasticity triggered by repetitive, high-intensity loading (M. Yamashita et al., 2023).

To systematically summarize the clinical paradox between anatomical adaptations and altered neuromuscular control, the distinct diagnostic findings from MRI and EMG evaluations in the rowing population are contrasted in Table 2.

Table 2. Comparison of structural (MRI) and functional (EMG) diagnostic findings in the lumbopelvic region of elite rowers

Diagnostic Modality	Primary Diagnostic Focus	Key Findings in the Rowing Population	Clinical Implication for Low Back Pain (LBP)
Magnetic Resonance Imaging (MRI)	Static anatomical evaluation of passive spinal structures (intervertebral discs, joints) and muscle morphometry (cross-sectional area).	Reveals prevalent microstructural matrix degradation, lower T2* values (loss of hydration), and higher Pfirrmann grades. Paradoxically demonstrates hypertrophy (larger cross-sectional area) of the multifidus and erector spinae in rowers with a history of LBP.	Structural abnormalities (e.g., disc degeneration) are highly prevalent even in completely asymptomatic athletes. Consequently, MRI findings alone do not reliably predict the onset or severity of clinical pain.
Surface Electromyography (EMG)	Dynamic functional evaluation of active neuromuscular control, muscle activation amplitudes, and firing timing during the stroke cycle.	Demonstrates excessive, compensatory activation of global superficial trunk muscles (thoracic/lumbar erector spinae, latissimus dorsi) during the drive phase in rowers with LBP compared to healthy controls.	Confirms that mechanical LBP in rowers is strongly driven by altered motor control, delayed reflexes, and protective muscular spasms, highlighting a functional rather than purely structural pathology.

Source: Own elaboration based on current literature.

7. Prevention Strategies: Pre-participation Screening and Core Endurance

Given the high physical demands of the sport, pre-participation screening is highly recommended to identify physical deficits predisposing rowers to low back pain (LBP). The Functional Movement Screen (FMS) has been effectively utilized in this context. The FMS evaluates seven fundamental movement patterns (including the deep squat, hurdle step, and in-line lunge) to identify potentially harmful movement asymmetries and compensations, scoring each task from 0 to 3 for a maximum composite score of 21 (S. Gonzalez et al., 2018; H. Clay et al., 2016). Research indicates that female collegiate rowers who scored 16 or lower on the FMS had a significantly greater risk of developing LBP during the season (S. Gonzalez et al., 2018; H. Clay et al., 2016).

The increased injury risk associated with low FMS scores is strongly correlated with deficits in core stabilization High-risk rowers (FMS score ≤16) exhibit significantly diminished core endurance, with average hold times of only 109.5 seconds on the isometric prone plank test, compared to 175.3 seconds in lower-risk individuals (S. L. Gonzalez et al., 2018). To enhance preventive strategies, global movement screens such as the FMS should be paired with specific functional assessments, including the Sorensen test, which specifically evaluates the endurance capacity of the posterior trunk extensor muscles.

Conventional static core conditioning is often inadequate for addressing these neuromuscular deficits. Recent clinical trials advocate for perturbation-based trunk stabilization training (PTT), which introduces sudden internal and external perturbations to sport-specific postures. This advanced sensorimotor approach targets proprioceptive deficits and enhances dynamic spinal stability by improving activation of deep stabilizing muscles in elite rowers (R. Schäfer et al., 2022).

In addition to movement screening, recent evidence underscores the role of biochemical markers and muscular balance in spinal health. Significant correlations have been identified between serum levels of cartilage oligomeric matrix protein (COMP), a biomarker for early cartilage breakdown, and the trunk flexor-to-extensor peak torque ratio (M. Ogurkowska et al., 2024). Since chronic muscular imbalances increase compressive forces on the intervertebral discs, conditioning programs should prioritize correcting strength discrepancies between trunk flexors and extensors. Furthermore, maintaining optimal vitamin D (25(OH)D) status is recommended to support skeletal muscle health and tissue regeneration during periods of intensive training (M. Ogurkowska et al., 2024).

Preventive conditioning should address the entire functional kinetic chain. Because the rowing stroke relies on efficient power transfer from the legs through the trunk to the upper extremities, optimizing lumbopelvic coordination and sequential muscle activation is essential. This integrated approach significantly reduces compensatory overloading of the lumbar spine, decreasing the risk of acute strains and chronic microtrauma (S. Arumugam et al., 2020).

8. Clinical Management and Return to Sport Protocols

Since the majority of mechanical lumbar spine dysfunction episodes in rowers stem from benign mechanical overload and cumulative microtrauma, most athletes respond highly favorably to non-operative clinical management (J. Mortazavi et al., 2015). The first line of conservative treatment typically includes a period of active rest, strategic modification of training loads, and the administration of nonsteroidal anti-inflammatory drugs (NSAIDs), paired with sport-specific physical therapy focused on core stabilization and lumbopelvic flexibility (J. Mortazavi et al., 2015). In the cases of acute structural overuse, such as active spondylolysis or severe discogenic pathology, rowers should temporarily avoid rowing and repetitive spinal flexion to promote optimal tissue healing and prevent further injury (J. Mortazavi et al., 2015). During this acute phase cardiovascular cross-training is encouraged, however athletes must strictly avoid activities that impose high vertical compressive loads on the healing spine, such as heavy barbell squats and repetitive stair running, until they are completely asymptomatic (T. M. Hosea and J. A. Hannafin, 2012).

Although conservative care is effective for most rowers, surgical intervention is indicated for cases of intractable pain persisting beyond 4 to 6 months of comprehensive management, or in the presence of progressive neurological deficits and unstable spondylolisthesis (J. Mortazavi et al., 2015). Surgical options vary according to the specific pathology and may include microdiscectomy or more complex interbody or posterolateral spinal fusion techniques (J. Mortazavi et al., 2015).

A successful Return to Sport (RTS) requires a cautious, graded, and highly individualized approach. Clearance timelines vary by injury type: returning to full competition following a general low back pain episode typically takes 3 to 4 months, while recovery from structural injuries like spondylolysis often requires 5 to 7 months (S. Arumugam et al., 2020). To ensure safety and reduce recurrence, athletes must meet objective clinical criteria, including a full, pain-free range of spinal motion and the restoration of at least 80% of their baseline muscle strength, core endurance and flexibility (J. Mortazavi et al., 2015). Furthermore, rowers must demonstrate the ability to maintain a mechanically sound, fatigue-resistant stroke during controlled ergometer sessions before advancing to dynamic, high-load on-water training (S. Arumugam et al., 2020). In the most severe cases requiring spinal fusion, athletes must complete a rehabilitation period of at least one year, with radiographic evidence confirming solid bone union before return (J. Mortazavi et al., 2015).

9. Discussion

The association between high intensity physical activity and lumbar spine dysfunction in rowers constitutes a major clinical paradox. Although moderate exercise generally protects the general population from back pain, the extreme mechanical load characteristic of elite rowing creates a distinct risk profile. Epidemiological evidence indicates that rowers have up to a 6.4

times higher odds of developing low back pain (LBP) compared to physically active non-rowing controls (K. Trompeter et al., 2017). This suggests that the standardized, extreme mechanical demands of sport effectively override the typical protective benefits of exercise, leading to high rates of cumulative microtrauma (V. Athy et al., 2023).

A major point of debate in injury etiology is the influence of biological sex. In adult elite populations, recent evidence suggests that the immense biomechanical stress of the stroke cycle affects spinal structures equally regardless of sex Research involving university rowers has found no statistically significant differences in LBP prevalence or severity between males and females (L. Heyneke and A. Green, 2021). Meta-analyses further corroborate that sex is not a significant independent risk factor among mature athletes (X. Ze et al., 2025) However, a distinct disparity exists in adolescent populations, where high school-aged females report significantly higher injury rates than their male peers (C. M. Baugh and Z. Y. Kerr, 2016). This gap emphasizes the urgent need for early movement screening and targeted core endurance interventions for adolescent female rowers before they reach technical and muscular maturity (S. L. Gonzalez et al., 2018).

Beyond physical factors, the chronic nature of rowing injuries is heavily influenced by the athletes' psychosocial perception of pain. Qualitative research reveals that rowers often view severe back pain as an inevitable, "normalized" consequence of the sport (M.B. Casey et al., 2022). This normalization fosters a dangerous "culture of concealment," in which athletes hide symptoms out of fear of losing their position or appearing weak to coaches and teammates (M.-B. Casey et al., 2022). Such fear-avoidant behaviors lead to altered movement patterns and delayed medical evaluation, which exacerbates long-term tissue damage (M.-B. Casey et al., 2022).

To address this issue, injury management strategies must transition from an exclusively biomedical approach to a comprehensive biopsychosocial model (M. B. Casey et al., 2022; V. Athy et al., 2023). The necessity of this integrated approach is most evident in ultra-endurance ocean rowing. During transoceanic races, rowers face unprecedented physiological and psychological stressors, including extreme sleep deprivation and chronic musculoskeletal pain (A. G. B. Willmott et al., 2025; W. J. H. Galsworthy et al., 2022). In these challenging conditions, both mental resilience and accurate threat appraisal are as critical to performance and injury prevention as biomechanical efficiency (W. J. H. Galsworthy et al., 2022). Breaking down the stigma of pain disclosure is therefore essential to ensure timely rehabilitation and prevent acute microtrauma from becoming career-ending pathology.

10. Conclusions

Mechanical lumbar spine dysfunction in rowers is a complex, multifactorial condition resulting from repetitive mechanical overload, prior injury, and maladaptive neuromuscular control (X. Ze et al., 2025; S. Osuka et al., 2023). While prolonged, static ergometer use is a major risk factor, this review emphasizes that prevention requires a wider perspective of the entire kinematic chain. For instance, the observed compensatory cervical spine extension at high stroke rates highlights the need for comprehensive postural and head control beyond the lumbar region (V. Giustino et al., 2022). Furthermore, addressing neuromuscular fatigue, particularly the delayed activation of paraspinal muscles during high-intensity 2000-m efforts, is essential to prevent the chronic overloading of passive spinal structures (T. Oshikawa et al., 2021).

Supportive strategies,such as equipment-based interventions and advanced functional screening, play a critical role in mitigating these risks. While subtle oar blade adjustments have minimal effects on muscle activation, high density textured insoles can optimize plantar pressure distribution and enhance symmetrical force application (B. van Trigt et al., 2026; T. Vieira et al., 2017). To prevent future injury, prioritizing perturbation-based trunk stabilization training (PTT) and specific core endurance assessments, including the Sorensen and isometric plank tests, is necessary (R. Schäfer et al., 2022; S. L. Gonzalez et al., 2018). These approaches are also critical for adolescent athletes, as global muscle strength and reactive stability underpin both long-term performance and injury prevention (B. Dingirdan Gultekinler and V. Bayrakc Tunay, 2026).

Ultimately, clinical management of these injuries must evolve from a strictly biomedical approach to a comprehensive biopsychosocial model. Clinicians and coaches must actively challenge the misconception that severe back pain is an inevitable outcome of rowing (M.-B. Casey et al., 2022; V. Athy et al., 2023). By addressing the "culture of concealment" and reducing fear-avoidance beliefs, sports organizations can promote early injury reporting. This change is important to ensure that athletes receiveeffective rehabilitation before acute microtrauma develops into chronic, career-ending pathology (M.-B. Casey et al., 2022; V. Athy et al., 2023).

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