A Critical Review of Form and Force Closure Concepts in Sacroiliac Joint Biomechanics

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Revised Academic Version – November 2024

Abstract

The sacroiliac joint (SIJ) has long been described using the concepts of form closure and force closure to explain load transfer, stability, and pain mechanisms within the lumbopelvic region. Originally proposed in the early 1990s, these concepts suggested that sacral stability is achieved through a keystone-like mechanism, relying on compressive forces between the sacrum and ilia. However, accumulating biomechanical, anatomical, and imaging evidence challenges the validity of this model.

This narrative review critically examines the form and force closure framework in light of contemporary scientific findings. The available literature suggests that ligamentous suspension, rather than bone-to-bone compression, plays the dominant role in SIJ load transfer, shock absorption, and motion control. Misinterpretation of degenerative changes and selective citation practices have contributed to the persistence of misleading biomechanical assumptions. A revised understanding of SIJ mechanics is essential for accurate clinical reasoning and effective musculoskeletal rehabilitation strategies.

Introduction

The sacroiliac joint occupies a central role in the transfer of loads between the spine and lower extremities. Due to its limited range of motion and complex ligamentous anatomy, the SIJ has historically been difficult to model biomechanically. In an attempt to explain its stability and function, the concepts of form closure and force closure were introduced and rapidly adopted in clinical and educational contexts.

Form closure describes the geometric congruence between the sacrum and ilia, implying inherent stability due to joint shape. Force closure refers to additional compressive forces generated by muscles and ligaments that purportedly increase joint stiffness and load transfer efficiency. Together, these concepts promote a keystone-based interpretation of pelvic mechanics. Despite their widespread acceptance, these models warrant critical re-evaluation.

Conceptual Background: Form and Force Closure

The keystone analogy suggests that the sacrum behaves as a wedge compressed between the ilia, transmitting axial loads directly through joint surfaces. According to this model, weight-bearing activities increase compression at the SIJ, enhancing stability through frictional resistance.

Force closure is described as the muscular and ligamentous augmentation of this compression. Muscles and ligaments are thought to actively increase joint stiffness by drawing the ilia together, thereby improving load transfer efficiency across the pelvic ring.

However, this conceptual framework presupposes sustained bone-to-bone compression at the articular surfaces—a premise that has been increasingly questioned by biomechanical evidence.

Biomechanical Considerations

Normal pelvic motion involves reciprocal movement of the ilia rather than symmetrical compression. During typical gait and postural adjustments, one ilium moves medially while the other moves laterally. Bilateral nutation, in which both ilia move medially, is rare and does not result in sacral compression due to spatial constraints imposed by the sacrum itself.

Importantly, approximation of the ilia does not equate to compression of the sacrum. The pelvis functions biomechanically more like a suspension system than a rigid keystone. The sacrum occupies space between the ilia and cannot be compressed in the manner implied by keystone mechanics.

Scientific Evidence on SIJ Contact and Load Transfer

The only direct investigation examining SIJ articular surface contact under load demonstrated that tight joint surface compression does not occur across physiological loading ranges. Vukicevic and colleagues reported that even under substantial load, consistent bone-to-bone contact was not achieved, provided the interosseous ligaments remained intact.

Conversely, removal of these ligaments resulted in abnormal sacral displacement and altered joint mechanics, underscoring the central role of ligamentous structures in maintaining SIJ stability. These findings directly contradict the premise that compressive joint contact is the primary mechanism of load transfer.

Degeneration and Misinterpretation

Degenerative changes of the SIJ have often been cited as evidence supporting compressive joint mechanics. However, extensive anatomical studies have demonstrated that degenerative features such as surface roughening, fibrosis, osteophyte formation, and partial ankylosis occur progressively with age and are not necessarily pathological adaptations to load transfer.

Some proponents of the form and force closure model have reinterpreted these degenerative findings as functional adaptations, selectively emphasizing early changes while downplaying clearly pathological alterations. Such interpretations risk conflating degeneration with normal biomechanical function.

Shock Absorption and Ligamentous Suspension

The musculoskeletal system functions as an integrated shock absorption network. Within this system, ligaments play a critical role in absorbing, storing, and releasing energy during movement. During nutation, axial forces transmitted from the spine are absorbed by tensioning of the SI ligaments rather than by articular surface compression.

At the end range of motion, stored elastic energy is released, contributing to efficient recoil and movement continuity. This ligamentous suspension mechanism allows for smooth, low-friction motion while protecting articular surfaces from excessive shear and compressive stress.

When ligamentous integrity is compromised, abnormal sacral motion may occur, leading to altered load distribution and potential pain generation.

Clinical Implications

Persisting reliance on keystone-based models may misguide clinical reasoning and intervention strategies. Treatments aimed at increasing compressive stiffness or promoting “closure” may overlook the importance of ligamentous integrity, neuromuscular coordination, and load modulation.

A ligament-dominant suspension model aligns more closely with observed biomechanics and provides a coherent framework for understanding SIJ dysfunction, movement variability, and pain mechanisms. This perspective supports rehabilitation approaches emphasizing controlled motion, load management, and neuromuscular integration rather than rigid stabilization.

Conclusion

The form and force closure model of sacroiliac joint biomechanics contains fundamental inconsistencies when evaluated against anatomical, biomechanical, and imaging evidence. While historically influential, the keystone-based interpretation fails to account for ligamentous suspension, reciprocal ilial motion, and the absence of sustained articular compression.

A revised model emphasizing ligament-mediated load transfer and shock absorption offers a more accurate representation of SIJ function. Recognizing the limitations of traditional closure concepts is essential for advancing both biomechanical understanding and clinical practice.

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Version Note

This manuscript represents a revised and expanded academic version of an earlier web-based publication. The current version reflects scientific updates and academic restructuring completed in **November 2024**.