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Editorial: Advancing musculoskeletal health: bridging basic and clinical research on biomechanical properties of joints, ligaments, tendons, and associated structures

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Editorial on the Research Topic
Advancing musculoskeletal health: bridging basic and clinical research on biomechanical properties of joints, ligaments, tendons, and associated structures

Introduction

Musculoskeletal disorders remain one of the leading causes of pain, disability, and socioeconomic burden worldwide. Across orthopedics, sports medicine, and rehabilitation, a deeper understanding of the biomechanical behavior of joints, ligaments, tendons, and associate structures is essential for advancing preventive, diagnostic, and therapeutic strategies. This Research Topic was conceived to bridge foundational biomechanical science with clinical application, highlighting how integrative and multidisciplinary approaches can illuminate the mechanisms underlying such musculoskeletal disorders. Collectively, the contributions address a wide spectrum of musculoskeletal structures and pathologies, spanning traumatic fractures, ligament and tendon injuries, degenerative disease, surgical techniques, and biological augmentation. By bringing basic science, imaging, computational modeling, cellular biology, and clinical research together, this Research Topic offers a comprehensive overview of current challenges and emerging solutions in musculoskeletal health research.

Computational modeling and imaging advances for mechanistic understanding of joint function

Several contributions in this Research Topic highlighted how computational modeling combined with high-resolution three-dimensional (3D) imaging enhanced diagnostic capacity and guide treatment optimization. These studies exemplified how imaging and engineering tools converge to reveal pathological load patterns, refine surgical planning, and support patient-specific biomechanical assessment.

Castillo et al. used computed tomography (CT)-based segmentation to construct patient-specific finite element models for analyzing cam-type femoroacetabular impingement. Their simulations demonstrated substantially elevated strain concentrations and altered load distribution during hip flexion and abduction in affected joints. These mechanistic insights help clarify the mechanical etiology of cartilage degeneration in femoroacetabular impingement and illustrate the role of computational modeling as a decision-support tool for surgical reshaping and rehabilitation strategies.

Similarly, Suarez-Hernandez et al. investigated the biomechanical consequences of SLAP (Superior Labrum Anterior Posterior) type II tears. By discretizing the shoulder joint anatomy into a comprehensive 3D model, they showed that the labrum did not effectively deepen the socket of the humeral head in the glenoid cavity, resulting in increased mobility of the humeral head, which is consistent with clinical presentations of instability. Their biomechanical modeling provides a strong foundation for evaluating how surgical interventions would restore load-bearing capacity in the shoulder.

Yang et al. further advanced the utility of computational biomechanics by developing a detailed finite element model of the halo–pelvic traction construct for spinal deformity correction. The developed computational models demonstrated high anatomical and biomechanical accuracy and could be used to design constructions that avoid excessive pin stress or unsafe displacement. Such modeling applications can further enable refinement of traction protocols and enhance procedural safety.

In addition to modeling, anatomical precision remains essential for accurate biomechanical interpretation. Xue et al. provided a thorough morphometric characterization of the sustentaculum tali using 3D CT reconstructions, and established normative values and sex-specific diagnostic thresholds for dislocation. These anatomical data have the potential to support more accurate surgical planning, optimal screw trajectory selection, and future computational modeling-based assessment of hindfoot biomechanics.

Biomechanical foundations of soft tissue healing and degeneration

Mechanobiological pathways, graft preparation strategies, and surgical repair outcomes are examined across the included studies, providing insight into the biological and mechanical factors that shape soft tissue healing. Across these investigations, a common message emerged wherein achieving optimal soft tissue healing depends on a delicate balance of mechanical environment, biological processes, and structural integrity. Integrating these components remains a critical frontier in biomechanical engineering.

Zhang et al. provided a mechanistic review of IL-1β-mediated pathways in tendinopathy, highlighting how proinflammatory signaling promotes matrix breakdown, cellular apoptosis, and dysregulated remodeling. Their synthesis underscored how tendinopathy is not purely a mechanical problem but rather the result of sustained molecular perturbations interacting with mechanical loading. The review identified key gaps in translational work and pointed to IL-1β as a promising but underdeveloped therapeutic target.

Ma et al. addressed a fundamental engineering challenge in ligament reconstruction: optimizing decellularized tendon processing. Their controlled evaluation of trypsin exposure demonstrated a clear duration-dependent trade-off: longer enzymatic treatment enhanced cell adhesion but progressively weakened mechanical strength. These quantitative relationships provide an important basis for balancing biological integration with structural integrity when preparing grafts for anterior cruciate ligament (ACL) reconstruction.

Chien et al. offered clinically grounded insight into Achilles tendon healing mechanics. Their retrospective analysis comparing repairs with and without human amniotic membrane (hAM) augmentation revealed that hAM use significantly reduced operative time, likely by simplifying soft tissue handling, without increasing complication rates or altering functional outcomes measured by AOFAS (American Orthopaedic Foot and Ankle Society) scores. Although hAM did not reduce re-rupture or infection rates, its ability to streamline the procedure without compromising tendon integrity suggests a promising adjunctive role. Importantly, complications such as re-rupture or infection were strongly associated with reduced functional scores, reinforcing how postoperative mechanical insufficiency directly affects long-term recovery.

Wang et al. case report of a supination–adduction ankle fracture with an associated ATFL (Anterior Talofibular Ligament) rupture further exemplified the importance of soft tissue stability for joint mechanics. Despite anatomically fixed fractures, talar tilt persisted until the ligament injury was recognized and repaired, demonstrating that restoring ligament tension is essential for achieving mechanically stable alignment.

Advances in surgical techniques, joint stability restoration, and functional recovery

Biomechanical principles are applied throughout the contributions to refine surgical techniques, enhance fixation strategies, and promote accelerated functional restoration. Across these studies, improved outcomes stemmed directly from better alignment between surgical techniques and the underlying mechanical behavior of musculoskeletal tissues.

Ma et al. reported significant clinical benefits of a lateral parapatellar approach combined with a "Hedgehog" Kirschner-wire tension band for comminuted patellar fractures. Enhanced visualization permitted more precise fragment reduction, while the optimized tension-band configuration promoted stable load-sharing across the patella. These mechanical advantages translated into improved functional scores, faster rehabilitation initiation, and reduced scar complications.

Capuzzo et al. described a rare case of congenital bilateral multidirectional glenohumeral hyperlaxity, managed with a combination of a posterior bone block and arthroscopic subscapularis augmentation. By reconstructing both static and dynamic stabilizers, the surgeons successfully restored shoulder centering and improved functional scores dramatically. This case illustrated how thoughtful biomechanical reconstruction could correct even profound shoulder joint instability.

Fan et al.'s review of post-traumatic elbow stiffness synthesized current management strategies and emphasized the biomechanical basis of motion loss. Capsular fibrosis, heterotopic ossification, and muscle imbalance disrupt elbow kinematics, and early mobilization remains central to preventing stiffness. Their work reinforced the notion that rehabilitation protocols must be finely tailored to mechanical constraints of healing tissues.

Finally, Wang et al. reviewed tranexamic acid use in arthroscopy, noting its comprehensive benefits in maintaining a clear operative field, stabilizing fluid dynamics, and reducing tissue swelling, supporting safer instrument manipulation and potentially improve surgical efficiency and postoperative function recovery.

Global insights into the burden of musculoskeletal diseases

From a viewpoint of trends in global public health, Chen et al. provided a comprehensive epidemiological analysis of knee dislocation over the past 3 decades, demonstrating increasing burden among older adults despite decreasing age-standardized incidence. Their finding that falls remain the predominant cause reinforced the need for targeted prevention strategies, while the positive association between disease burden and the sociodemographic index suggested that lifestyle, healthcare access, and activity patterns contribute to evolving injury mechanics. These population-level insights offer valuable guidance for biomechanical research, including the design of fall-mitigation technologies, improved protective devices, and age-specific rehabilitation strategies.

Conclusion: toward an integrative future for musculoskeletal biomechanics

Fundamentally, research on the biomechanical response of musculoskeletal tissues seeks to explain how biological structures bear loads, distribute stress, respond to injury, and adapt to interventions. The breadth of research represented in this Research Topic demonstrates the vitality and diversity of contemporary musculoskeletal biomechanics. From surgical technique innovation and computational modeling to molecular insights and global epidemiology, these studies collectively highlight the value of bridging basic and clinical science.

As the field advances, future research should prioritize patient-specific computational modeling, integrative mechanobiological studies, and translational approaches that deliver laboratory discoveries to meaningful clinical applications. By continuing to bridge basic biomechanics with clinical innovation, we can move toward more effective, personalized, and mechanistically grounded care for patients suffering from musculoskeletal disease.

Author contributions

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