Mechanical Characterization of the Liver and Kidney: A Systematic Review

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Introduction:

Understanding the mechanical behavior of soft abdominal organs is critical for accurately predicting injury mechanisms, improving computational human body models, and informing injury prevention strategies. While injury biomechanics research has extensively characterized skeletal, cardiovascular, and pulmonary tissues, the liver and kidneys remain among the least mechanically defined organs, despite their high incidence of injury in blunt impact, automotive collisions, and sports-related trauma. Existing mechanical data for these organs are largely derived from short-duration or high strain-rate testing, limiting the ability to model injury progression under sustained or complex loading conditions.

Objective:

This review examines the current state of soft tissue mechanical characterized with a focus on the liver and kidneys, highlighting key gaps that hinder injury prediction and model biofidelity.

Methodology:

A systematic review of the available literature was conducted to determine the breadth and depth of available knowledge regarding the mechanical properties of the liver and kidney across various loading rates and conditions.

Results:

Both organs experience continuous pressure fluctuations during normal physiology and are subjected to combined compressive, tensile, and shear loads during traumatic events. However, the time-dependent mechanical responses of both organs such as creep, stress relaxation, and load redistribution are poorly understood. These viscoelastic behaviors are particularly relevant for injury biomechanics, as they influence how stresses evolve within the organ during prolonged loading, delayed rupture, and post-impact deformation.

Limitations in available mechanical data contribute to simplified material representations in computational human body models, which may underpredict organ deformation or fail to capture injury thresholds accurately. The lack of standardized testing protocols for abdominal soft tissues further complicates cross-study comparisons and model validation. Drawing from advances in soft tissue testing and scaffold mechanics, this review underscores the need for organ-specific, time-dependent mechanical benchmarks derived from human tissue.

Conclusions:

Continued experimental testing of liver and kidney tissue using post-mortem human subjects is identified as a critical step toward addressing these gaps. In particular, viscoelastic testing under physiology relevant loading conditions can provide essential parameters for improving material models used in injury

simulations. Incorporating creep and stress relaxation data will enhance predictions of injury onset, progression, and severity in scenarios involving sustained compression or complex loading paths.

By shifting focus beyond impact-only characterization toward comprehensive time-dependent mechanical behavior, injury biomechanics research can significantly improve the accuracy of abdominal organ injury modeling. Expanded mechanical testing of the liver and kidneys will strengthen the link between experimental data, computational simulations, and injury mitigation strategies, ultimately advancing the field's ability to predict and prevent soft tissue injury.