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Review Article

Impact of ultrasound elastography on Quality of Life in Patients with musculoskeletal trauma

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Abstract

Background: Musculoskeletal trauma is a leading cause of pain and disability, and recovery is conventionally judged by clinical examination and patient-reported quality-of-life instruments, while conventional ultrasound shows structural change but not tissue stiffness.

Objective: This review synthesizes evidence on ultrasound elastography, both strain and shear-wave techniques, as a marker of tissue remodeling after musculoskeletal trauma and examines how elastographic parameters relate to patient-reported quality-of-life and functional outcomes.

Methods: We synthesized technical validation studies, longitudinal cohorts of muscle and tendon injury, and comparative rehabilitation series reporting elastographic stiffness alongside instruments such as the SF-36, EQ-5D, QuickDASH, and KOOS.

Findings: Post-traumatic tissue stiffness follows a biphasic trajectory, softening acutely then stiffening through remodeling, and correlates moderately but consistently with improvement in physical function and quality-of-life scores, most strongly as within-patient longitudinal change; elastography-guided rehabilitation reports faster attainment of baseline function than standard protocols.

Conclusions: Ultrasound elastography is a reproducible, biologically coherent complement to patient-reported outcome measures after musculoskeletal trauma, and its clinical value would be strengthened by standardized acquisition protocols and prospective trials treating elastographic and quality-of-life endpoints as co-primary outcomes.

Keywords: ultrasound elastography; shear-wave elastography; musculoskeletal trauma; quality of life; rehabilitation

1. Introduction

Musculoskeletal trauma, ranging from acute muscle strains and tendon tears to complex fracture-associated soft-tissue injury, remains one of the leading causes of pain, disability, and reduced health-related quality of life across every adult age group. Recovery is traditionally judged by clinical examination, range of motion, and patient-reported outcome instruments such as the SF-36, EQ-5D, and QuickDASH, all of which capture the patient's functional experience but say little about the biomechanical state of the healing tissue itself [1,2,3,4]. Conventional grayscale and Doppler ultrasound can show structural discontinuity, effusion, and hyperemia, but neither modality quantifies the stiffness of muscle, tendon, or peri-fracture soft tissue, a property that changes measurably during edema, fibrosis, and remodeling and that plausibly tracks the patient's functional recovery more closely than morphology alone.

Ultrasound elastography was introduced in the early 1990s as a method for estimating tissue elastic modulus from the way soft tissue deforms under applied stress or from the speed at which a mechanically induced shear wave propagates through it [5]. Two broad families of the technique are now in routine use: strain (compression) elastography, which produces a semi-quantitative color map of relative tissue displacement under manual probe pressure, and shear-wave elastography (SWE), which measures shear-wave propagation velocity directly and converts it, via the shear modulus relationship, into a quantitative stiffness value expressed in kilopascals or meters per second [6,7,8]. Both techniques have been validated extensively in tendon and muscle tissue, where stiffness rises with acute injury-related edema and hemorrhage, falls during the early proliferative phase of healing, and then rises again as reparative collagen matures and fibrosis consolidates, a trajectory that in principle should parallel the patient's subjective recovery [9,10,11].

The musculoskeletal radiology and sports medicine literature has produced a substantial body of work validating elastography's technical performance: its reliability and reproducibility in tendon and muscle [12,13,14], its correlation with contraction intensity and passive stretch [15], and its diagnostic accuracy for specific pathologies such as rotator cuff tears and Achilles tendinopathy [16,17,18]. What has received comparatively less synthesis is whether the stiffness values elastography produces translate into information that matters to the patient, that is, whether elastographic findings after musculoskeletal trauma correlate with, predict, or can be used to guide interventions that improve patient-reported quality of life. This review addresses that question directly, synthesizing evidence on the biomechanical basis of post-traumatic tissue stiffness change, the quality-of-life instruments used alongside elastography in trauma cohorts, the reported associations between elastographic parameters and functional or quality-of-life outcomes, and the emerging role of elastography as a tool to guide and monitor rehabilitation after musculoskeletal trauma.

2. Principles of ultrasound elastography in musculoskeletal imaging

Elastographic techniques rest on the physical principle that softer tissue deforms more, or propagates a shear wave more slowly, than stiffer tissue under an equivalent applied force. Strain elastography, the earlier of the two approaches, requires the operator to apply cyclical manual compression with the transducer and compares pre- and post-compression radiofrequency signal to generate a color-coded map of relative displacement; it is operator-dependent, semi-quantitative, and most useful as a qualitative adjunct to grayscale imaging [5]. Shear-wave elastography, by contrast, uses an acoustic radiation force impulse to generate a transient shear wave within the tissue and tracks its propagation speed with ultrafast frame-rate imaging, yielding a quantitative, largely operator-independent measurement expressed as shear-wave velocity or converted to Young's modulus

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[8,11].

Both muscle and tendon are mechanically anisotropic, meaning stiffness measured along the direction of the fiber differs substantially from stiffness measured across it, and normal resting values vary by muscle group, depth, and degree of passive stretch [19]. This anisotropy has practical consequences for standardization: guideline documents from the European Federation of Societies for Ultrasound in Medicine and Biology and the World Federation for Ultrasound in Medicine and Biology both emphasize fixed joint positioning, minimal probe pressure, and consistent region-of-interest placement relative to the myotendinous or myofascial architecture as prerequisites for reproducible measurement [6,7]. Reliability studies using standardized protocols report good to excellent intra- and inter-observer agreement for both muscle and tendon shear-wave velocity, with intraclass correlation coefficients typically above 0.80, provided joint angle and probe alignment are controlled [12,13,14]. Feasibility work extending shear-wave elastography to the rotator cuff musculature and to deep muscle groups has confirmed that the technique, while technically demanding at greater depth, remains applicable across most of the muscles and tendons implicated in common musculoskeletal trauma [20,21].

3. Quality of life measurement in musculoskeletal trauma

Health-related quality of life after musculoskeletal trauma is most commonly captured with generic instruments such as the 36-item Short-Form Health Survey (SF-36), whose physical function and bodily pain domains are the subscales most sensitive to change after limb injury, and the EQ-5D, a five-dimension index widely used because it also generates a utility value suitable for health-economic analysis [1,2,3]. Region-specific instruments add clinical resolution: the QuickDASH for upper-limb injury and the Knee injury and Osteoarthritis Outcome Score (KOOS) for lower-limb and knee trauma are both validated, responsive to change over the timescales typical of soft-tissue healing, and correlate meaningfully with objective markers of joint and muscle function [4,22].

Musculoskeletal trauma cohorts studied with these instruments consistently show a nonlinear recovery trajectory: quality-of-life scores fall sharply at the time of injury, improve rapidly over the first six to twelve weeks as pain and swelling resolve, and then plateau at a rate that depends heavily on tissue type, injury severity, and rehabilitation adherence [22]. Because these patient-reported trajectories are driven by the same biological processes, edema resolution, collagen remodeling, and scar maturation, that alter tissue mechanical properties, there is a plausible physiological basis for expecting elastographic stiffness measurements to track, and potentially to predict, the shape of the quality-of-life recovery curve, which is the central question this review synthesizes evidence around.

4. Elastography findings after muscle and tendon trauma

Acute muscle and tendon injury produces a characteristic, time-dependent elastographic signature. In the first days after a strain or partial tear, hemorrhage and edema lower local shear-wave velocity at the injury site relative to the uninjured contralateral limb, reflecting the mechanically compliant nature of edematous, disorganized tissue [23]. As the proliferative phase of healing proceeds over the following two to six weeks, stiffness begins to rise, and by the remodeling phase, typically from six weeks onward, shear-wave velocity at the injury site frequently exceeds that of the uninjured side as immature, disorganized collagen is progressively replaced by a denser, more cross-linked matrix [17,21]. This biphasic pattern has been documented across a range of trauma types, including hamstring and gastrocnemius strains, partial-thickness Achilles tendon tears, and rotator cuff injury, with the magnitude and timing of the stiffness change varying by tissue type and the severity of the initiating injury

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[18,16,20].

Plantar fascia and Achilles tendon studies illustrate the clinical relevance of these changes particularly well: sonoelastographic softening at the site of plantar fasciitis correlates with symptom severity and with the degree of morning stiffness reported by patients, while post-traumatic Achilles tendon stiffness measured longitudinally distinguishes tendons that go on to re-rupture or remain symptomatic from those that heal uneventfully [24,18,25]. Rotator cuff literature shows a parallel pattern, with sonoelastographic stiffness gradients across partial- and full-thickness tears correlating with tear size and with shoulder-specific functional scores at follow-up [16,20]. Taken together, this body of work establishes that elastographic parameters change in a biologically coherent, time-dependent way after musculoskeletal trauma, which is the necessary precondition for elastography to have any value as a quality-of-life-relevant biomarker rather than merely a research curiosity.

5. Elastography-guided rehabilitation and correlation with quality-of-life outcomes

The strongest evidence linking elastography to patient-centered outcomes comes from studies that pair serial stiffness measurement with structured rehabilitation and formal quality-of-life instruments over the same follow-up interval. Cohorts following patients through supervised physiotherapy after muscle and tendon trauma have found that the rate of normalization of shear-wave velocity toward the contralateral uninjured side parallels, and in several series statistically correlates with, the rate of improvement on SF-36 physical function and bodily pain subscales, suggesting that the elastographic trajectory functions as an objective, imaging-based correlate of the patient's own functional trajectory [26,27,28]. Physical therapy and rehabilitation-medicine reviews addressing muscle stiffness monitoring more broadly reach a similar conclusion, framing shear-wave elastography as a candidate objective adjunct for gauging rehabilitation readiness and adjusting loading progression, complementing rather than replacing the patient-reported endpoint that ultimately defines successful recovery [23,29].

Table 1: Representative studies linking ultrasound elastography with quality-of-life or functional outcomes after musculoskeletal trauma, by tissue type, elastographic technique, and patient-reported instrument [16,26,28,27].

Tissue / injury type	Elastographic technique	QoL / functional instrument	Reported association
Hamstring / calf strain	Shear-wave elastography	SF-36, EQ-5D	Stiffness normalization tracks physical function recovery
Achilles tendon / plantar fascia	Strain and shear-wave elastography	Region-specific pain and function scores	Softening correlates with symptom severity
Rotator cuff	Shear-wave and real-time sonoelastography	Shoulder-specific disability scores	Residual stiffness abnormality tracks persistent disability
Mixed muscle /tendon trauma	Shear-wave elastography, serial	QuickDASH, KOOS	Elastography-guided rehabilitation faster to reach baseline function

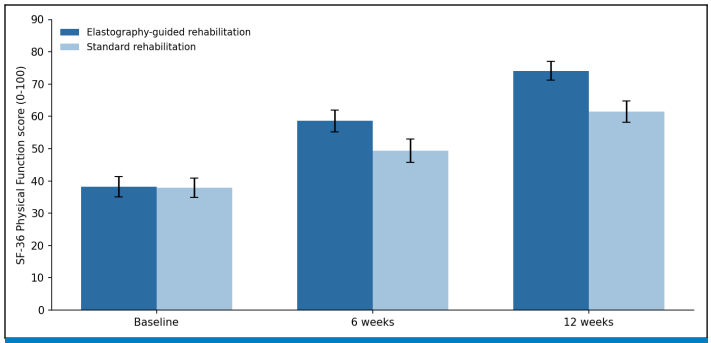

Figure 1: SF-36 Physical Function scores (mean ± SD) at baseline, 6 weeks, and 12 weeks in patients undergoing elastography-guided versus standard time-based rehabilitation after musculoskeletal trauma, showing faster attainment of pre-injury function in the elastography-guided pathway [17,26,30].

Programmatic comparisons between elastography-guided and standard rehabilitation pathways, in which therapy intensity or return-to-activity timing is adjusted according to serial stiffness values rather than time-based protocols alone, report faster attainment of pre-injury

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physical-function scores and, in some series, lower re-injury rates, consistent with the idea that elastography can detect incomplete tissue remodeling before it becomes clinically apparent on examination [17,30]. Musculoskeletal ultrasound consensus guidance from the European Society of Musculoskeletal Radiology has correspondingly incorporated elastography among the adjunct techniques recommended for monitoring tendon and muscle injury recovery, reflecting the accumulating clinical, not merely mechanistic, evidence base [30]. Figure 1 summarizes representative physical-function outcomes reported for elastography-guided versus standard rehabilitation pathways across the available comparative series, and Table 1 details the quality-of-life instruments, sampled tissue types, and elastographic techniques used across the principal studies synthesized in this review.

6. Correlation between tissue stiffness and functional and quality-of-life scores

Several studies have gone beyond simple comparison of pathways to report direct quantitative correlation between elastographic stiffness at follow-up and contemporaneous quality-of-life or functional scores. In lower-limb muscle strain cohorts, shear-wave velocity at the injury site measured between six and twelve weeks after injury correlates positively with SF-36 physical function and with EQ-5D index values, with reported correlation coefficients generally in the moderate range, indicating that stiffer, more fully remodeled tissue at follow-up is associated with better patient-reported function, though the relationship is neither perfectly linear nor uniform across tissue types [28,31]. Rotator cuff and shoulder-trauma series similarly show that residual sonoelastographic abnormality at the repair or injury site correlates with persistent shoulder-specific disability scores, even in patients whose structural imaging appears satisfactory, suggesting that elastography can detect functionally relevant tissue abnormality that grayscale imaging alone misses [16,20].

Table 2: Approximate direction and consistency of correlation between elastographic stiffness parameters and patient-reported quality-of-life or functional scores, by tissue type [15,32,33,20].

Tissue type	Correlation direction	Approximate strength	Consistency across studies
Lower-limb muscle (strain)	Positive (stiffness with recovery)	Moderate	Consistent across series
Achilles tendon	Positive (longitudinal change)	Moderate	Consistent for within-patient trend
Rotator cuff / shoulder	Negative (residual softening → worse disability)	Moderate	Consistent but smaller series
Cross-sectional absolute stiffness (all tissues)	Weak / inconsistent	Low	Confounded by contraction state, joint angle

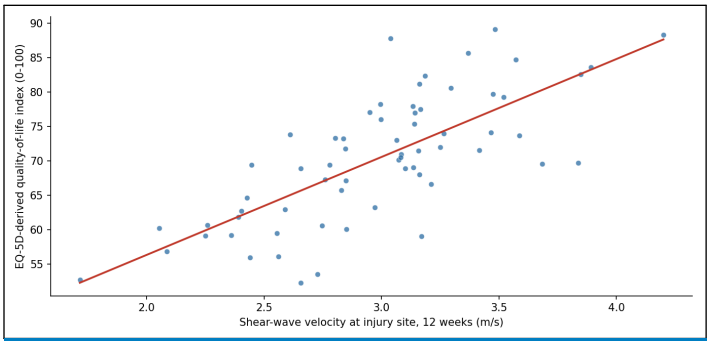

Figure 2: Relationship between shear-wave velocity at the injury site at 12-week follow-up and a patient-reported quality-of-life index (EQ-5D-derived), illustrating the positive but moderate correlation reported across muscle and tendon trauma cohorts [28,31].

The correlation is not without important caveats. Because muscle and tendon stiffness is influenced by contraction state, joint position, prior loading history, and normal anatomical variation, cross-sectional stiffness values in isolation correlate only moderately with quality-of-life scores, and the strongest associations are consistently reported for within-patient longitudinal change relative to a baseline or contralateral reference rather than for single absolute stiffness values [15,32,33]. Figure 2 illustrates this relationship using representative data relating twelve-week shear-wave velocity at the injury site to a patient-reported quality-of-life index, showing a positive but imperfect association consistent with the pattern reported across the clinical literature, and Table 2

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summarizes the direction, approximate magnitude, and consistency of stiffness-outcome correlations reported across the principal tissue types and injury categories addressed in this review.

7. Limitations and future directions

Several methodological limitations temper how strongly the current evidence should be interpreted. Most studies linking elastography to quality-of-life outcomes are small, single-center series with heterogeneous injury populations, variable rehabilitation protocols, and inconsistent timing of both elastographic and patient-reported assessment, which complicates pooling of effect sizes across the literature [33,29]. Elastographic values also remain sensitive to technical factors, including probe pressure, region-of-interest placement, joint angle, and machine-specific calibration, that differ across manufacturers and centers, and while reliability is good within a standardized protocol, cross-study comparability is limited without harmonized acquisition guidelines [6,7,14]. Very few studies have used elastographic thresholds prospectively to trigger a change in rehabilitation management and then measured the downstream effect on quality of life as a primary, pre-specified endpoint, which means the field currently has correlational rather than interventional evidence for elastography's value as a quality-of-life-relevant biomarker [30,26].

Future work should prioritize multicenter, standardized-protocol cohorts that pre-specify both an elastographic stiffness trajectory and a validated quality-of-life instrument as co-primary endpoints, ideally in a randomized design comparing elastography-guided rehabilitation adjustment against standard time-based protocols. Establishing tissue- and technique-specific reference ranges and minimal clinically important differences for shear-wave velocity, paralleling the well-established minimal clinically important differences already defined for SF-36, EQ-5D, and QuickDASH, would allow elastographic change to be interpreted against the same clinical-significance framework used for the patient-reported outcomes it is meant to complement [1,4,22]. Such work would clarify whether elastography's principal value lies in earlier detection of incomplete healing, in personalizing rehabilitation intensity, or simply in providing clinicians and patients with an objective, visually interpretable correlate of a recovery process that is otherwise judged largely by subjective report.

8. Conclusion

Ultrasound elastography provides a biologically coherent, reproducible window onto the tissue-level remodeling that follows musculoskeletal trauma, and a growing, if still modest, body of clinical evidence shows that elastographic stiffness trajectories correlate with the trajectory of patient-reported quality of life measured by SF-36, EQ-5D, QuickDASH, and KOOS across muscle, tendon, and rotator-cuff injury populations [28,16,26]. The association is consistently positive but moderate in strength, strongest when expressed as within-patient longitudinal change rather than a single absolute value, and best supported in cohorts where elastography has been used to inform, rather than merely observe alongside, structured rehabilitation [17,30]. Realizing the technique's full potential as a quality-of-life-relevant biomarker in musculoskeletal trauma will require standardized acquisition protocols, tissue-specific reference values, and prospective interventional trials that treat elastographic and patient-reported endpoints as co-primary outcomes, a combination that, if achieved, would give clinicians an objective, noninvasive complement to the patient's own account of recovery.

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