P-23

Clinical Validity of Shear Wave Elastography for Post-Stroke Spasticity: A Systematic Review and Meta-Analysis

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Background & Objectives

Post-stroke spasticity affects 25–43% of stroke survivors, contributing to pain, contracture, and functional decline

MAS & MTS are the clinical standard but limited by subjectivity and examiner variability. Neither directly quantifies passive muscle stiffness

Shear Wave Elastography (SWE) provides device-generated, quantitative stiffness values (m/s or kPa) from ultrasound. However, whether SWE meaningfully correlates with clinical ratings — and under what conditions — remains unclear

Objectives: ① Estimate pooled SWE–spasticity correlation using Robust Variance Estimation (RVE) ② Identify protocol-related moderators: scale type, position,

Methods

Study Design: Systematic review & meta-analysis (PRISMA 2020 · PROSPERO CRD420251232085)

Search: PubMed · Web of Science · CINAHL · Cochrane Library (inception, Dec 2025)

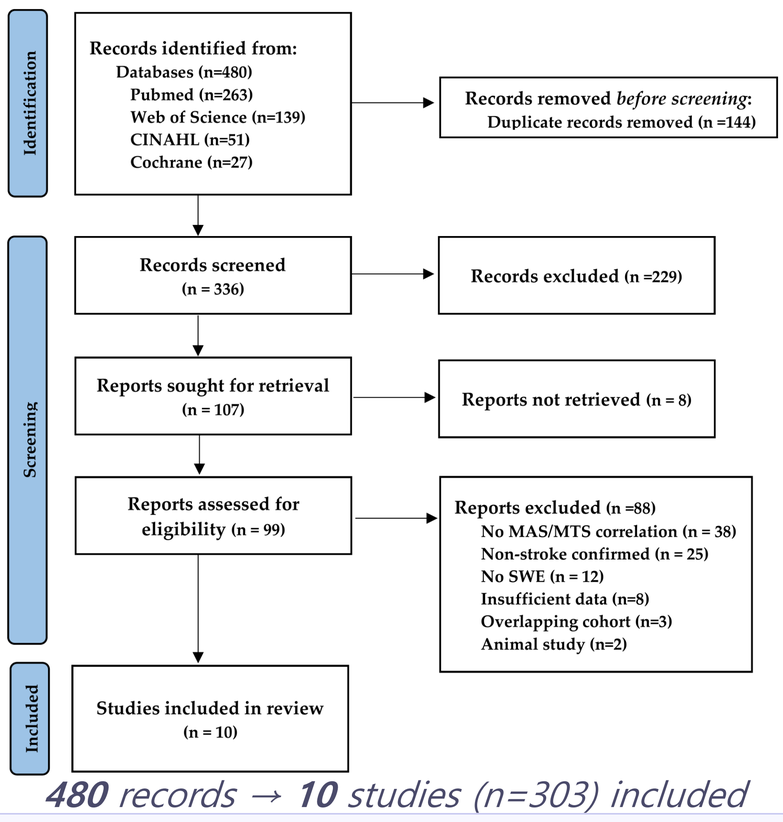
Eligibility: Adults with stroke; SWE performed in paretic muscle; clinical rating with MAS and/or MTS; extractable Pearson or Spearman correlation coefficient

Analysis:

- Random-effects meta-analysis with RVE
- Subgroup analyses by scale, position, metric, limb, chronicity
- Multivariable meta-regression (scale + position + metric)
- Publication bias: contour-enhanced funnel plot, Egger's test, trim-and-fill

Risk of Bias: COSMIN construct-validity criteria (9 checks; worst-score rule)

Study Selection (PRISMA 2020)



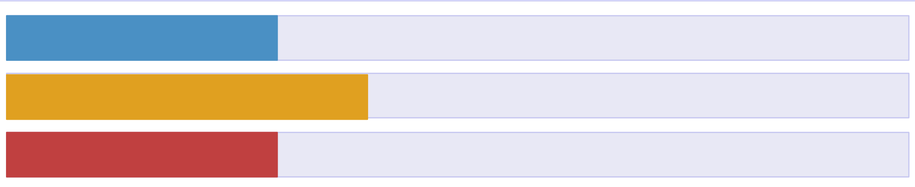
***480** records → **10** studies (n=303) included*

Study Characteristics (10 studies · 303 participants · 38 effect sizes)

Author	Year	N	Chronicity	Muscle(s)	Position	Scale	Metric	k
Analan et al.	2020	24	Chronic	BB	STRETCH	MAS	m/s	1
Cao et al.	2022	20	Subacute	MG	Both	MAS	kPa	3
Galvao et al.	2022	11	Chronic	BB, BR	STRETCH	MAS	kPa	2
Gao et al.	2019	7	Chronic	BB	Both	MAS/MTS	m/s	4
Hasegawa et al.	2023	10	Chronic	MG	Both	MAS/MTS	m/s	8
Jia et al.	2023	20	Subacute	AD,LD,PM,TM	Both	MAS	kPa	8
Lai et al.	2023	59	Subacute	FCR,FCU,FDS	REST	MAS/MTS	m/s	6
Liu et al.	2020	60	Subacute	BB	STRETCH	MAS	m/s, kPa	2
Wei et al.	2022	61	Subacute	BB	STRETCH	MAS	m/s	2
Wu et al.	2017	31	Subacute	BB	REST	MAS/MTS	m/s	2

Abbreviations:
AD = anterior deltoid; BB = biceps brachii; BR = brachioradialis; FCU = flexor carpi ulnaris; FCR = flexor carpi radialis; FDS = flexor digitorum superficialis; LD = latissimus dorsi; MAS = Modified Ashworth Scale; MG = medial gastrocnemius; MTS = Modified Tardieu Scale; PM = pectoralis major; TM = teres major; m/s = shear-wave speed; kPa = Young's modulus, k= effect sizes

Risk of Bias (COSMIN Construct-Validity)



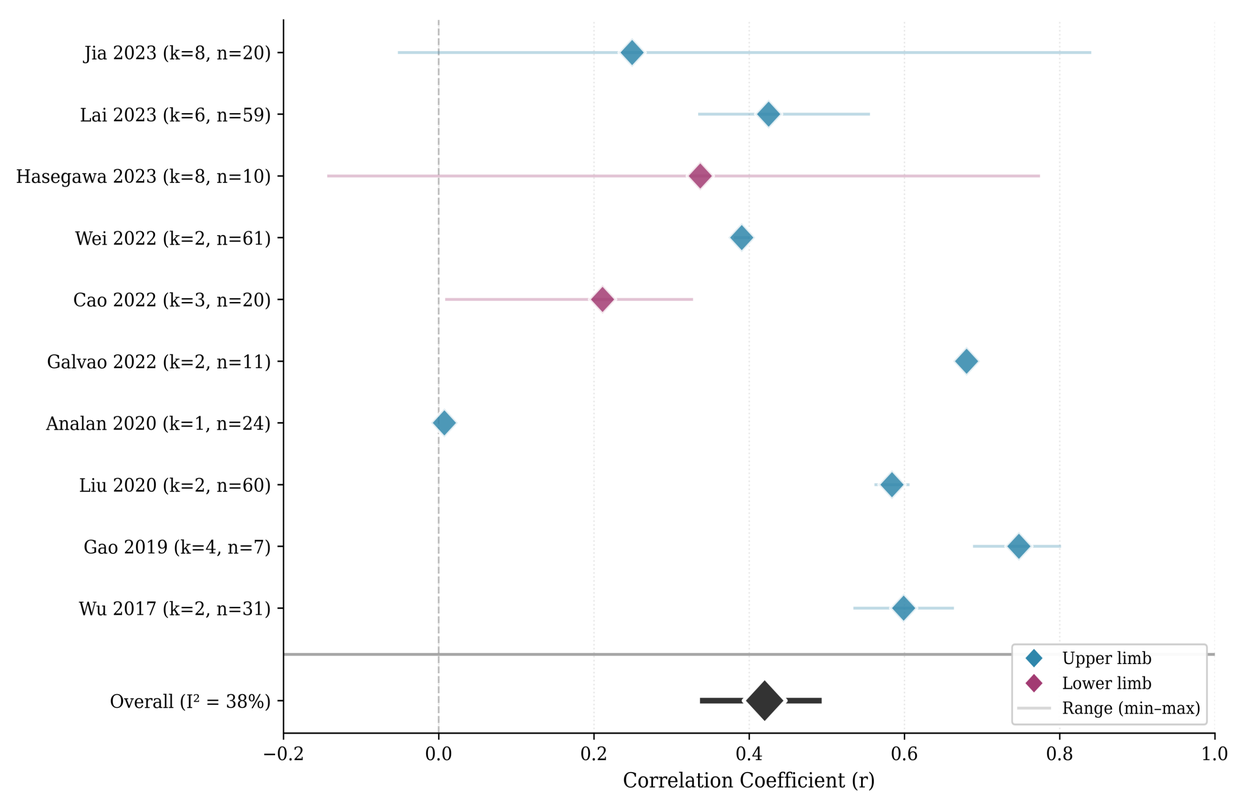
↓ *Small sample size (n<30 in 7/10) and incomplete assessor blinding reporting were the most common downgrading factors*

KEY FINDING

Pooled correlation: **r = 0.42** (95% CI 0.34 – 0.49)

10 studies · N = 303 · k = 38 effect sizes · I^2 = 38% · 95% PI: [0.11, 0.66]

Overall Association — Forest Plot



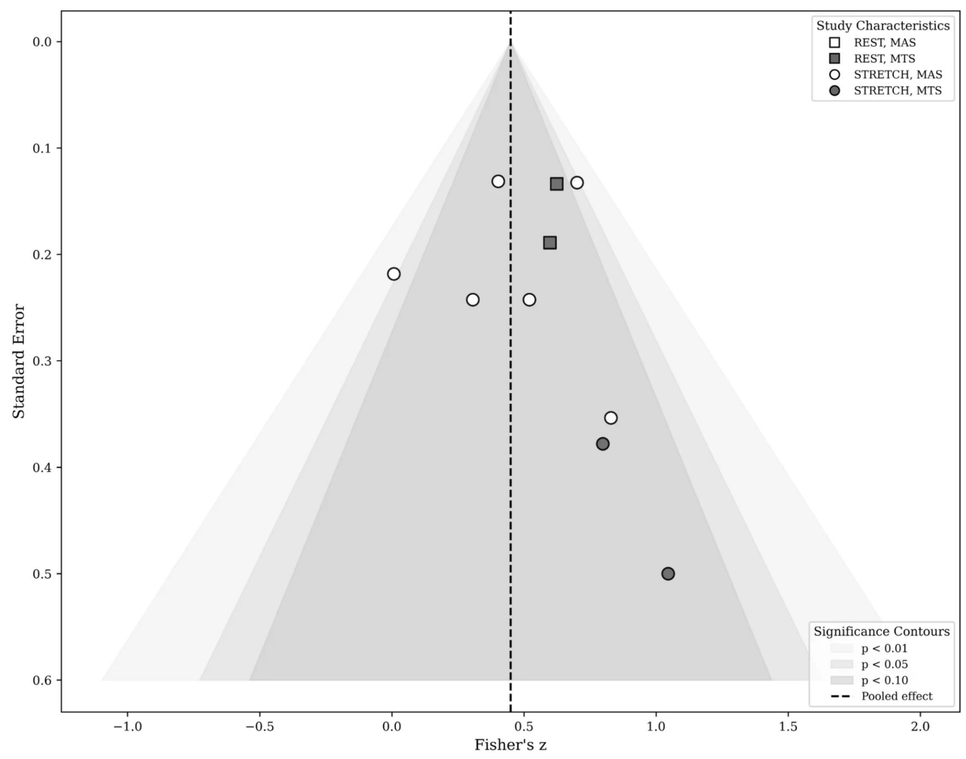
- ***Marker** = mean r within study; **Line** = within-study range*
- ***Blue** = upper limb; **Purple** = lower limb*

Subgroup Analysis Results

Subgroup	m/k	r	95% CI	95% PI	I^2	p
Scale						
MAS	10/26	0.39	[0.28, 0.49]	[−0.01, 0.68]	51%	0.13
MTS	4/12	**0.49**	[0.38, 0.59]	[0.38, 0.59]	0%	—
Measurement Position						
REST	6/20	0.38	[0.28, 0.47]	[0.18, 0.54]	19%	0.08
STRETCH	8/18	**0.49**	[0.35, 0.61]	[0.06, 0.76]	49%	—
Output Metric						
m/s	7/24	0.43	[0.32, 0.53]	[0.03, 0.72]	45%	0.34
kPa	4/14	0.40	[0.25, 0.53]	[0.18, 0.58]	16%	—
Limb Segment						
Upper limb	8/27	0.45	[0.35, 0.53]	[0.12, 0.69]	43%	0.10
Lower limb	2/11	0.30	[0.09, 0.48]	[0.09, 0.48]	0%	—
Stroke Chronicity						
Subacute	6/23	0.41	[0.31, 0.50]	[0.08, 0.67]	48%	0.92
Chronic	4/15	0.46	[0.28, 0.61]	[0.14, 0.69]	11%	—
Overall	**10/38**	**0.42**	**[0.34, 0.49]**	**[0.11, 0.66]**	**38%**	**—**

★ *Multivariable meta-regression (scale+position+metric): overall QM=8.4, p=0.04*

Publication Bias — Funnel Plot



Contour-enhanced funnel plot (Fisher's z scale)
No marked asymmetry / Egger's test p=0.28

Conclusions & Clinical Implications

① Moderate association — SWE as quantitative adjunct

- SWE captures **passive mechanical stiffness** but not neural reflex hyperexcitability
- **It complements — does not replace — clinical rating scales**

② Prioritize MTS over MAS

- **MTS-based correlations (r=0.49)** significantly exceeded MAS-based (r=0.39)
- MTS separately quantifies the velocity-dependent catch (R1) and passive range (R2), aligning more closely with what SWE measures under quasi-static conditions

③ Standardize stretched measurement position

- **STRETCH** conditions yielded **r=0.49** vs. REST r=0.38 (β=+0.20, p=0.10)
- Stretched positions increase passive tension, improving stiffness discrimination

④ Metric, limb, chronicity: no significant moderation

- Output metric (m/s vs. kPa) did not significantly affect results
- Evidence remains limited for lower-limb muscles

Future Directions

- **Protocol standardization**: report joint angle, position, and muscle depth systematically to enable meta-analytic pooling
- **MTS component studies**: adequately powered trials reporting R1 and R2 correlations separately to disentangle neural vs. structural contributions
- **Lower-limb and gait-context studies**: SWE during functionally relevant positions (weight-bearing, dynamic) for lower-limb spasticity
- **Longitudinal designs**: tracking SWE responsiveness alongside clinical scales after botulinum toxin or rehabilitation interventions