MMSx AUTHORITY · APPLIED BIOMECHANICS LAB

Shoulder Rehabilitation

50 Evidence-Based Biomechanics Analyses

50 titles · four analysis slides each · movement analysis, verified research data, decision pathways and APA 7 references

AUTHOR

Dr. Neeraj Mehta, PhD

ORCID 0000-0001-6200-8495

MMSx Authority Institute for Movement Mechanics & Biomechanics Research, Inc.

DOI 10.5281/zenodo.23735725

Version 1 · 24 October 2026 · CC BY 4.0

Online edition: mmsxauthority.org/edu/analysis/shoulder/

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM — NOT A POSTURE MODEL.

SHOULDER REHAB CHALLENGE

Contents (1/2)

01	Why does my shoulder hurt? Understanding common causes and movement sensitivity	p. 4
02	Shoulder pain when lifting your arm: what the painful arc tells us	p. 8
03	Subacromial pain (impingement): why the old "pinching" explanation is changing	p. 12
04	Rotator cuff tendinopathy: how load, not rest, guides recovery	p. 16
05	Rotator cuff tear: does every tear need surgery?	p. 20
06	Rotator cuff tears on MRI: why many painless shoulders have them too	p. 24
07	Frozen shoulder: the freezing, frozen and thawing phases explained	p. 28
08	Frozen shoulder and diabetes: why stiffness behaves differently	p. 32
09	Shoulder pain at night: sleep positions and symptoms worth checking	p. 36
10	Pain reaching behind your back: what limited internal rotation means	p. 40
11	Pain reaching overhead: how the shoulder blade shares the load	p. 44
12	Shoulder blade movement (scapular dyskinesis): when it matters and when it doesn't	p. 48
13	Winging shoulder blade: muscle weakness or nerve problem?	p. 52
14	Rounded shoulders and posture: does correcting it reduce pain?	p. 56
15	Thoracic spine stiffness: can the upper back change shoulder loading?	p. 60
16	Shoulder bursitis: what the inflamed bursa can and cannot explain	p. 64
17	Calcific tendinitis: sudden severe shoulder pain and what helps	p. 68
18	Long head of biceps pain: pain at the front of the shoulder	p. 72
19	Labral tear (SLAP): clicking, catching and deep shoulder pain	p. 76
20	Shoulder dislocation: what happens to the joint, and the risk of it happening again	p. 80
21	Shoulder instability: when the shoulder feels loose or slips	p. 84
22	Hypermobile shoulders: building control without forcing range	p. 88
23	AC joint pain: pain on top of the shoulder	p. 92
24	Shoulder pain or neck pain? Why the source of arm pain matters	p. 96
25	Weakness lifting the arm: when to suspect a large cuff tear	p. 100

Mehta, N. (2026). Shoulder Rehabilitation: 50 Evidence-Based Biomechanics Analyses. MMSx Authority Applied Biomechanics Lab. https://doi.org/10.5281/zenodo.23735725

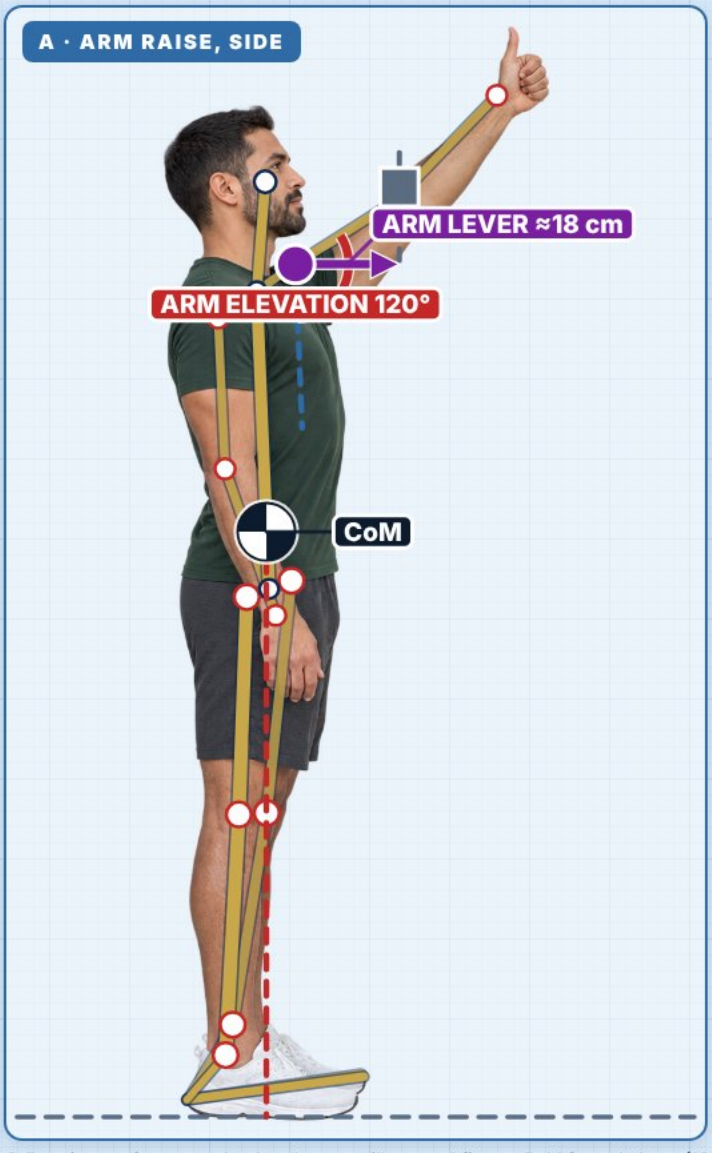
Contents (2/2)

26	Shoulder injection or exercise: what the evidence shows over time	p. 104
27	Subacromial decompression surgery: what the CSAW and FIMPACT trials found	p. 108
28	After rotator cuff repair: why early loading must be graded	p. 112
29	After shoulder replacement: regaining reach, strength and daily function	p. 116
30	After a shoulder dislocation: returning to sport and contact	p. 120
31	Shoulder pain during bench press: grip width, depth and load	p. 124
32	Shoulder pain during overhead press: range, bar path and trunk position	p. 128
33	Shoulder pain during push-ups: hand position and scapular control	p. 132
34	Pull-ups and hanging with shoulder pain: building tolerance safely	p. 136
35	Swimmer's shoulder: stroke volume, technique and fatigue	p. 140
36	Throwing shoulder: why the whole kinetic chain matters	p. 144
37	Tennis and padel shoulder pain: serve mechanics and load management	p. 148
38	Volleyball and overhead-sport shoulder pain: spiking, blocking and recovery	p. 152
39	Golf and shoulder pain: the lead shoulder and swing load	p. 156
40	Desk work and shoulder pain: reach, mouse position and movement breaks	p. 160
41	Carrying bags and children: everyday shoulder loads that add up	p. 164
42	Shoulder pain after 60: strength, cuff health and independence	p. 168
43	Shoulder pain in menopause: frozen shoulder risk and staying active	p. 172
44	External rotation strength: why the cuff's weakest direction matters	p. 176
45	Scapular exercises: who benefits from shoulder blade training?	p. 180
46	Pain during shoulder rehabilitation: when to modify, pause or seek help	p. 184
47	A shoulder pain flare-up: how to adjust your training plan	p. 188
48	Fear of moving a painful shoulder: how avoidance changes movement	p. 192
49	Is your shoulder rehabilitation working? Track function alongside pain	p. 196
50	Shoulder red flags: when shoulder pain needs urgent medical care	p. 200

Mehta, N. (2026). Shoulder Rehabilitation: 50 Evidence-Based Biomechanics Analyses. MMSx Authority Applied Biomechanics Lab. https://doi.org/10.5281/zenodo.23735725

WHY DOES MY SHOULDER HURT? UNDERSTANDING COMMON CAUSES AND MOVEMENT SENSITIVITY

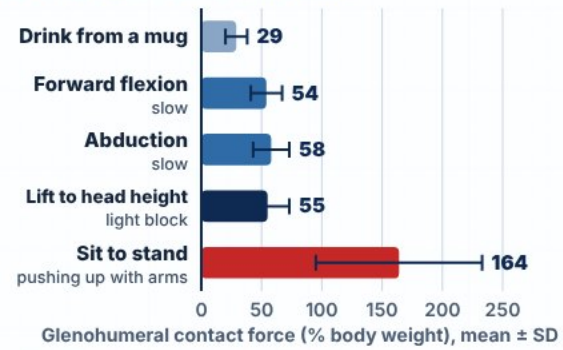
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Raising the arm is a lever problem

- Arm elevated **120°** in front of the body: the arm's weight acts about **18 cm** from the joint, **≈6 N·m** that the cuff and deltoid must hold.
- Most shoulder pain comes from the rotator cuff and subacromial tissues, the joint itself, the AC joint, or is referred from the neck.

Everyday tasks load the joint



25 adults, 26 daily tasks; musculoskeletal model estimates, not implant measurements. Klemt et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

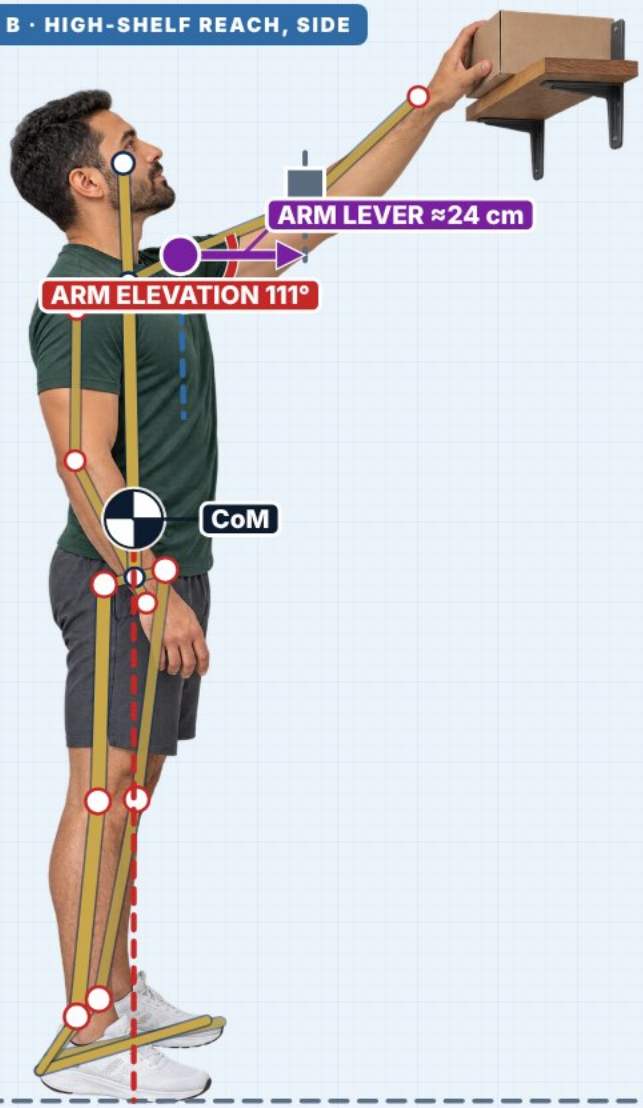
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WHY DOES MY SHOULDER HURT? UNDERSTANDING COMMON CAUSES AND MOVEMENT SENSITIVITY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

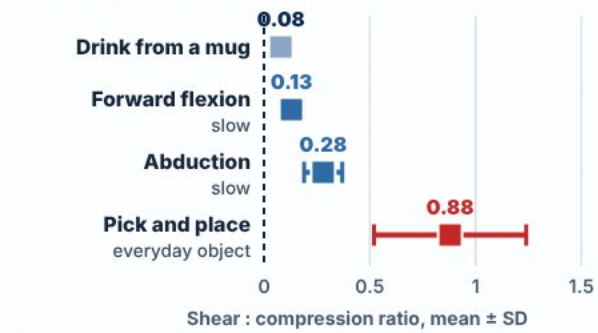
B · HIGH-SHELF REACH, SIDE



Reaching high: more lever, more shear

- Reaching to the shelf, arm at **111°**: the hand sits **≈46 cm** in front of the joint, so even a 1 kg box raises the moment to **≈13 N·m**.
- Some tasks ask the cuff to resist shear as well as compression, one reason awkward reaching can feel provocative with a light object.

Not all light tasks are equal



Same 25 adults; ratio above 0.5 in 8 of 26 tasks (highest 1.09 reaching across the body). Klemt et al. (2018).

Key point: this is a mechanical association that helps grade tasks, not proof of what causes pain.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

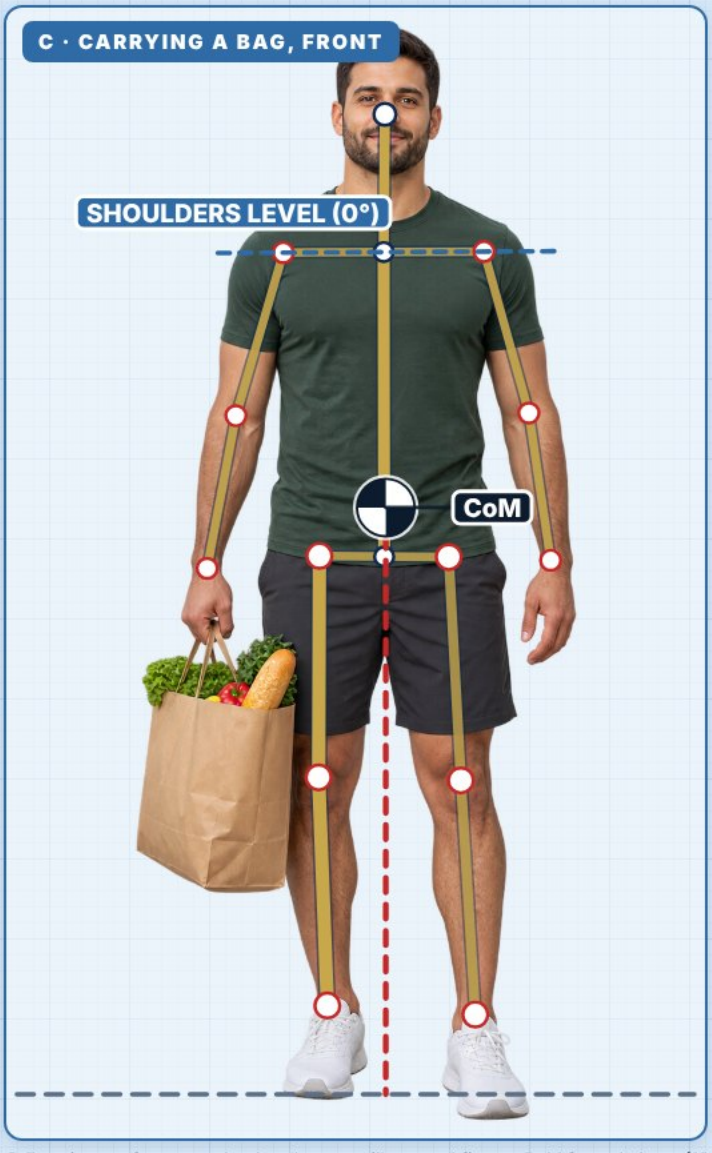
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WHY DOES MY SHOULDER HURT? UNDERSTANDING COMMON CAUSES AND MOVEMENT SENSITIVITY

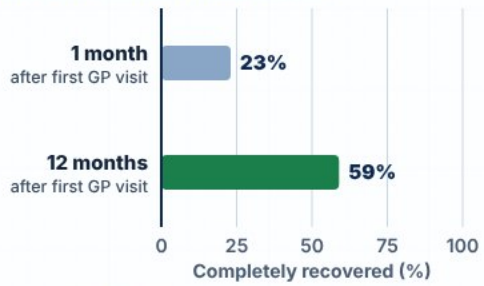
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Carrying with the arm at the side

- Bag held with the arm hanging, shoulders level (**0°**): the load hangs almost straight under the joint, so the lever is small.
- Pain intensity, symptom duration and neck pain predicted a poorer outcome; range, strength and arm dominance did not.

How new shoulder pain settles



349 new episodes, 11 Dutch general practices; 41% still had symptoms at 12 months. van der Windt et al. (1996).

Myth: "I need a scan before I start." Subacromial pain is a clinical diagnosis; imaging is not needed to begin treatment.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

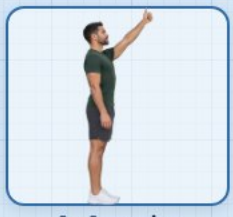
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WHY DOES MY SHOULDER HURT? UNDERSTANDING COMMON CAUSES AND MOVEMENT SENSITIVITY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Arm raise
Lever ≈18 cm

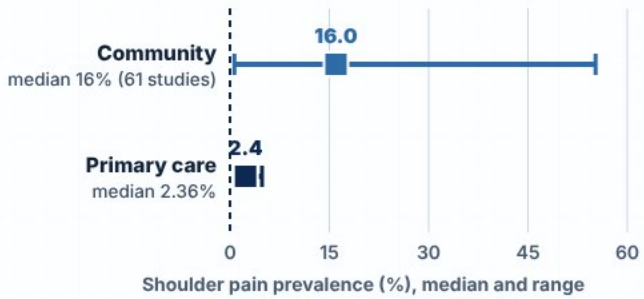


B · High reach
≈13 N·m



C · Carrying
Load under the joint

Shoulder pain is common



Wide ranges reflect different definitions; primary-care incidence median 37.8 per 1000 per year. Lucas et al. (2022).

Decision pathway

1. **SCREEN**
   Check the neck, fracture, infection and other serious causes; most shoulder pain is a clinical diagnosis.
2. **LOAD**
   Progressive exercise for the cuff and shoulder blade is the core treatment; adjust lever and dose to symptoms.
3. **REVIEW**
   Most improve within three months; refer if there is no improvement by 12 weeks.

NOT RECOMMENDED

Routine imaging before trying treatment; prolonged rest in a sling.

SEEK ASSESSMENT IF

Suspected fracture or dislocation, a hot swollen shoulder, a lump, several painful joints, or shoulder pain with chest pain or breathlessness.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Kooijman, M. K., Barten, D.-J. A., Swinkels, I. C. S., Kuijpers, T., de Bakker, D., Koes, B. W., & Veenhof, C. (2015). Pain intensity, neck pain and longer duration of complaints predict poorer outcome in patients with shoulder pain – a systematic review. *BMC Musculoskeletal Disorders, 16*, 288. https://doi.org/10.1186/s12891-015-0738-4

Lucas, J., van Doorn, P., Hegedus, E., Lewis, J., & van der Windt, D. (2022). A systematic review of the global prevalence and incidence of shoulder pain. *BMC Musculoskeletal Disorders, 23*, 1073. https://doi.org/10.1186/s12891-022-05973-8

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

van der Windt, D. A., Koes, B. W., Boeke, A. J., Devillé, W., De Jong, B. A., & Bouter, L. M. (1996). Shoulder disorders in general practice: Prognostic indicators of outcome. *British Journal of General Practice, 46*(410), 519–523.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

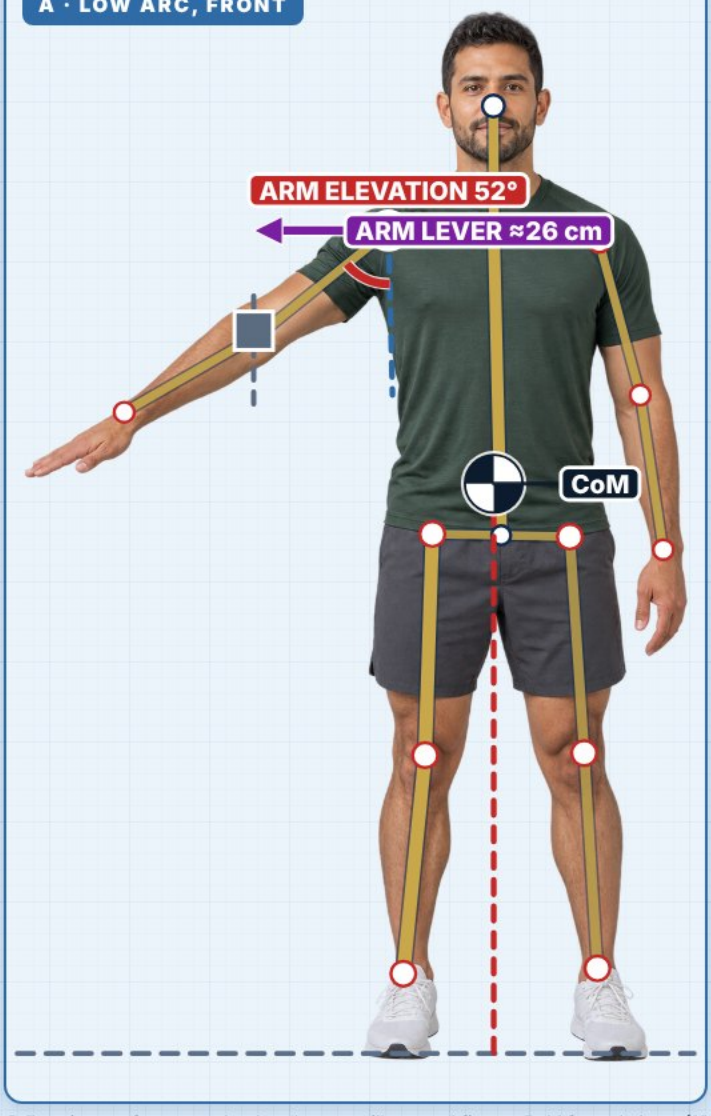
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN WHEN LIFTING YOUR ARM: WHAT THE PAINFUL ARC TELLS US

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

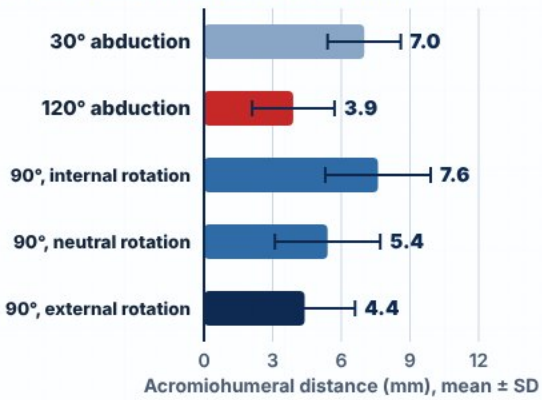
A · LOW ARC, FRONT



Early in the arc: low demand

- Arm raised **52°** out to the side with the elbow straight: the arm's weight acts about **26 cm** from the joint, **≈9 N·m** for the cuff and deltoid.
- The space under the acromion is widest low in the range; on 3-D MR imaging it roughly halved between 30° and 120° of abduction in volunteers.

The space narrows in every shoulder



Volunteers, open MR imaging; minimal distance between acromion and humeral head. Graichen et al. (1999).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

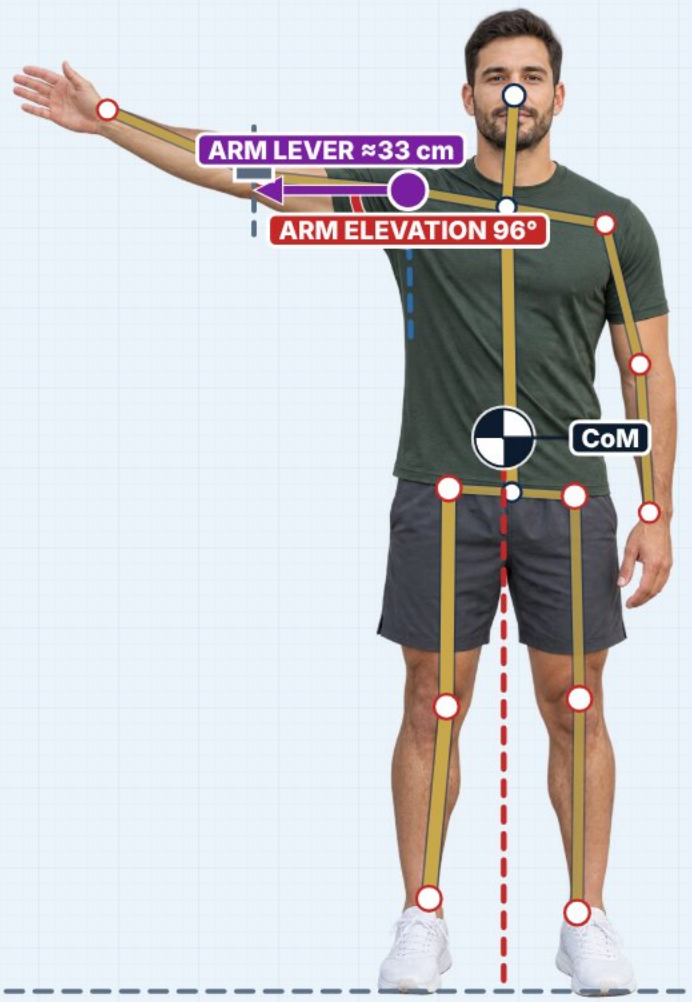
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN WHEN LIFTING YOUR ARM: WHAT THE PAINFUL ARC TELLS US

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

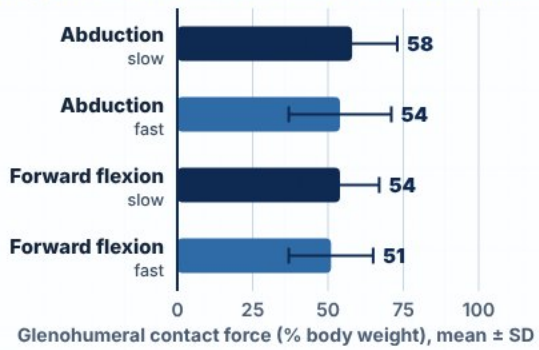
B · SHOULDER HEIGHT, FRONT



Mid-arc: the longest lever

- At **96°**, near shoulder height, the straight arm holds its weight furthest out: lever **≈33 cm**, moment **≈11 N·m**, the largest of the three frames.
- This is the range where a painful arc is classically felt; bending the elbow or shortening the arc reduces the lever while the shoulder is sensitive.

Raising the empty arm already loads the joint



25 adults; musculoskeletal model estimates, not implant measurements. Speed changed load little. Klemt et al. (2018).

Key point: a painful arc reflects load and position sensitivity in part of the range, not proof that a structure is being damaged.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN WHEN LIFTING YOUR ARM: WHAT THE PAINFUL ARC TELLS US

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

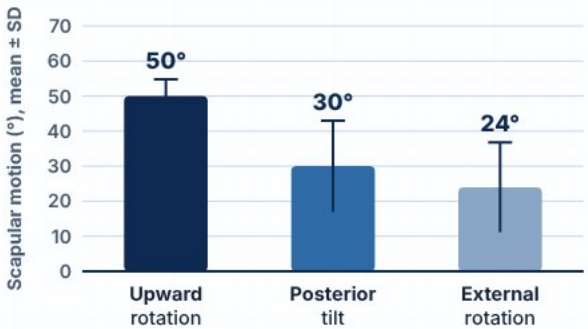
C · ARM OVERHEAD, FRONT



Overhead: the shoulder blade helps

- Arm at **156°**, almost vertical: the lever shortens to **≈11 cm** (**≈4 N·m**), one reason pain often eases at the top of the arc.
- The shoulder blade rotates upwards, tilts back and turns outwards as the arm rises; most tilt and outward rotation occur above 90°.

Shoulder blade motion, rest to full elevation



Healthy volunteers, bone pins in scapula and humerus; arm-to-blade ratio 1.7 : 1. McClure et al. (2001).

Myth: "A painful arc means the tendon is pinched or torn." The test has only moderate accuracy and the space narrows in every shoulder.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN WHEN LIFTING YOUR ARM: WHAT THE PAINFUL ARC TELLS US

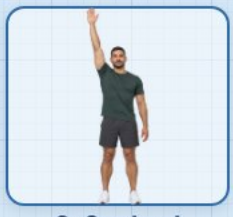
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Low arc
Lever ≈26 cm

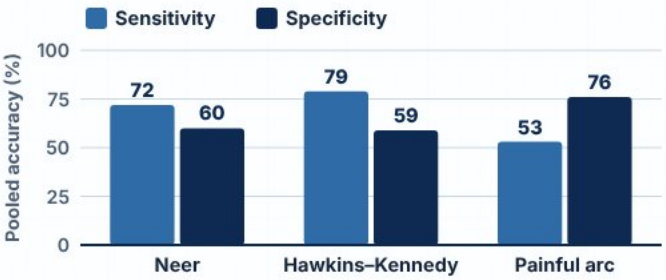


B · Mid arc
≈11 N·m, longest lever



C · Overhead
Lever ≈11 cm

One test cannot confirm the source



Pooled meta-analysis values for subacromial impingement; a positive arc raises suspicion modestly. Hegedus et al. (2012).

Decision pathway

1. **ASSESS**
   Take a full history and screen for red flags; combine the arc with other tests rather than relying on one sign.
2. **LOAD**
   Start progressive exercise; grade the lever with a bent elbow, a smaller arc and lighter weights.
3. **REVIEW**
   Consider a single injection if no better by 6–8 weeks; refer if no improvement by 12 weeks.

NOT RECOMMENDED

Routine imaging before treatment; repeated steroid injections.

SEEK ASSESSMENT IF

Inability to lift the arm after an injury, suspected fracture or dislocation, a hot swollen shoulder, a lump, or several painful joints.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Graichen, H., Bonel, H., Stammberger, T., Englmeier, K.-H., Reiser, M., & Eckstein, F. (1999). Subacromial space width changes during abduction and rotation: A 3-D MR imaging study. *Surgical and Radiologic Anatomy, 21*(1), 59–64. https://doi.org/10.1007/BF01635055

Hegedus, E. J., Goode, A. P., Cook, C. E., Michener, L., Myer, C. A., Myer, D. M., & Wright, A. A. (2012). Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systematic review with meta-analysis of individual tests. *British Journal of Sports Medicine, 46*(14), 964–978. https://doi.org/10.1136/bjsports-2012-091066

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

McClure, P. W., Michener, L. A., Sennett, B. J., & Karduna, A. R. (2001). Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. *Journal of Shoulder and Elbow Surgery, 10*(3), 269–277. https://doi.org/10.1067/mse.2001.112954

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

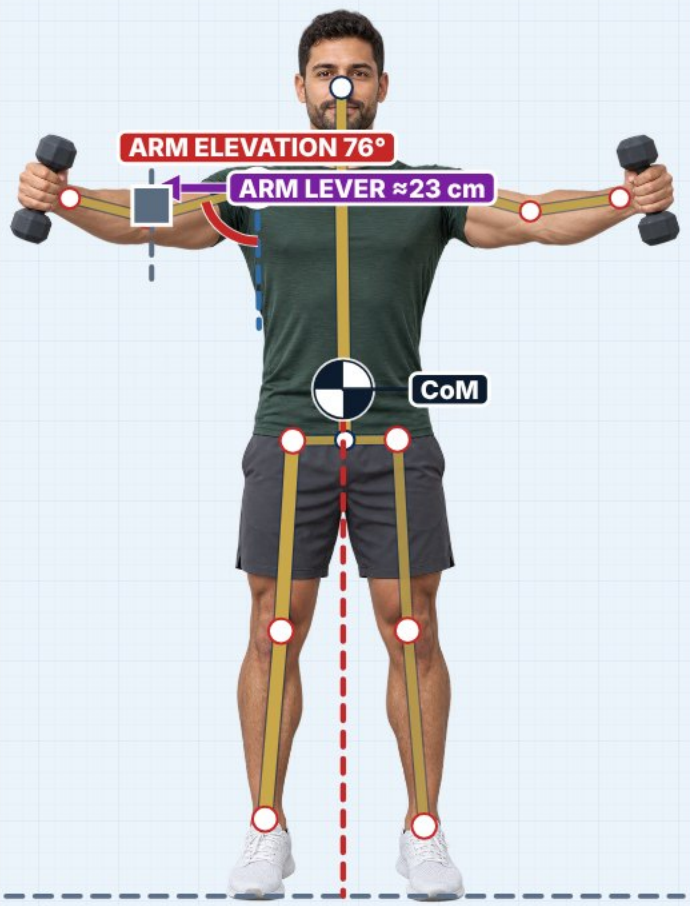
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL PAIN (IMPINGEMENT): WHY THE OLD "PINCHING" EXPLANATION IS CHANGING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

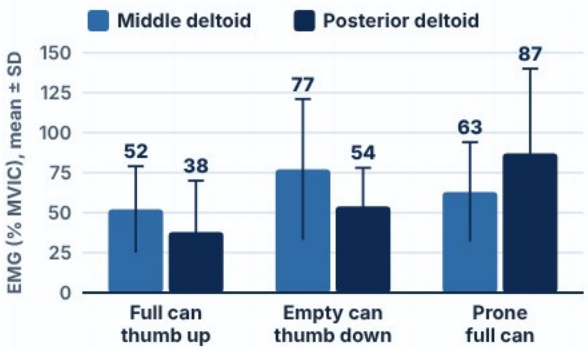
A · SCAPTION RAISE, FRONT



Thumb-up raise in the scapular plane

- Arms raised **76°** about 30° forward of the side, thumbs up: each arm's own weight acts **≈23 cm** from the joint, **≈8 N·m** before the dumbbell is added.
- Supraspinatus activity did not differ significantly between full-can, empty-can and prone raises, but the thumb-up version used the least deltoid.

Same cuff work, less deltoid



Healthy participants, fine-wire and surface EMG; MVIC = maximal voluntary isometric contraction. Reinold et al. (2007).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Dumbbell weight is not included. Educational, not diagnostic.

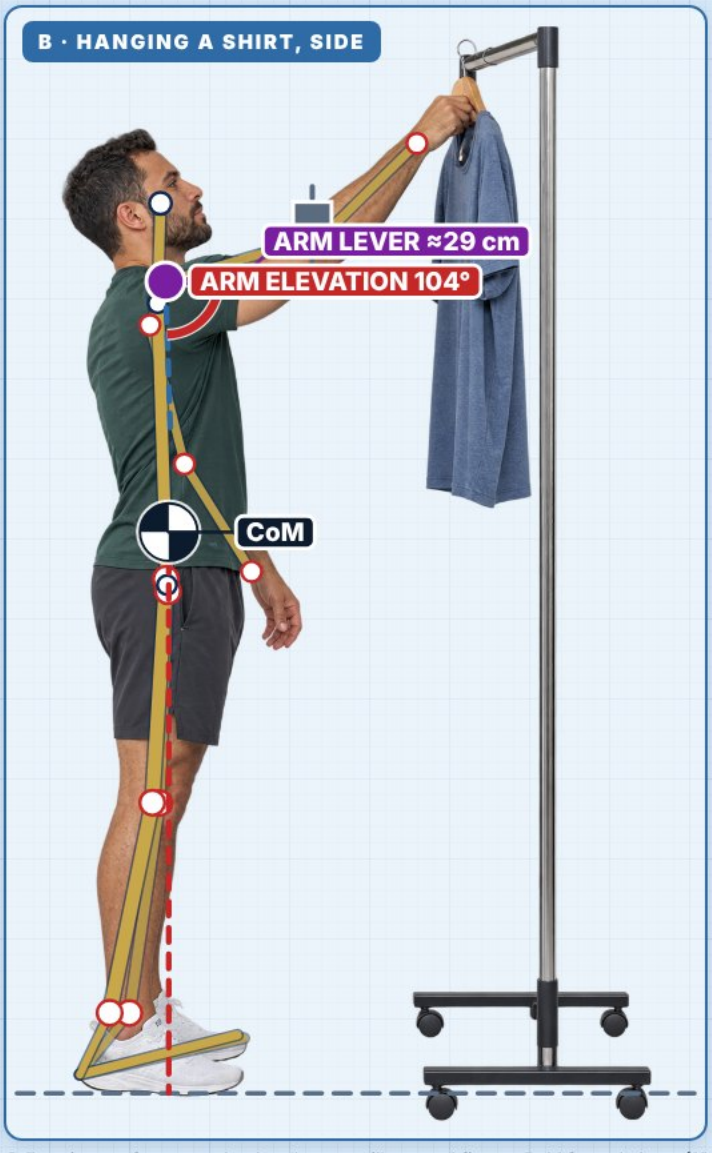
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL PAIN (IMPINGEMENT): WHY THE OLD "PINCHING" EXPLANATION IS CHANGING

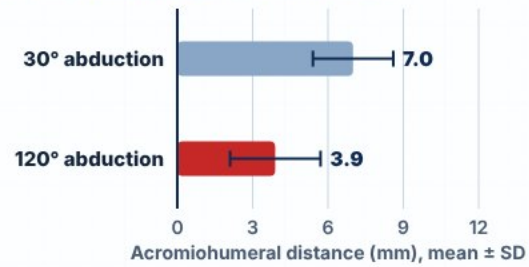
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Reaching overhead: narrowing is normal

- Hanging a shirt on a high rail, arm at **104°**: lever **≈29 cm**, **≈10 N·m**. Repeated overhead reaching is a common trigger of lateral shoulder pain.
- The space under the acromion narrows in every shoulder as the arm rises, so narrowing alone cannot explain why one shoulder hurts and another does not.

The space halves as the arm rises



Volunteers, 3-D open MR imaging; $p < 0.0001$ for 120° vs 30°. Graichen et al. (1999).

Myth: "The bone is pinching the tendon, so it has to be shaved." In a placebo-controlled trial, sham arthroscopy matched decompression.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

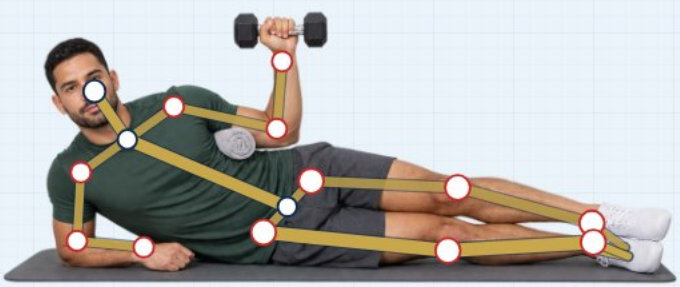
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL PAIN (IMPINGEMENT): WHY THE OLD "PINCHING" EXPLANATION IS CHANGING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

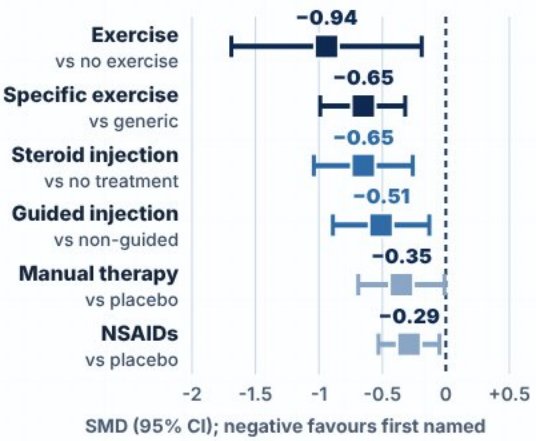
C · SIDE-LYING ROTATION, FRONT



Loading the cuff, arm supported

- Lying on the side with the elbow tucked against a towel, the dumbbell is rotated upwards against gravity: the cuff works while the arm stays low and supported.
- Across trials, exercise had the largest pooled effect, and specific exercise beat generic exercise; passive options gave smaller effects.

What helps subacromial pain?



Meta-analysis of randomised trials in adults with shoulder impingement, searches to January 2017. Steuri et al. (2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in lying positions, so no angles are quoted for this frame. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL PAIN (IMPINGEMENT): WHY THE OLD "PINCHING" EXPLANATION IS CHANGING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Scaption
≈8 N·m per arm

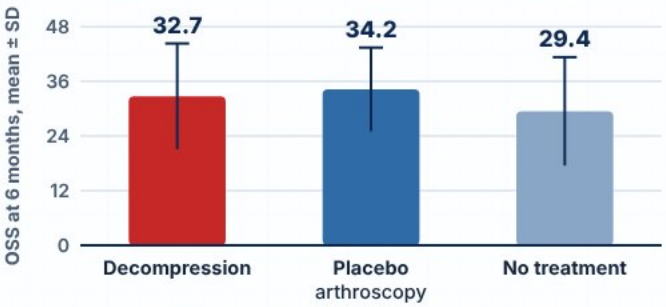


B · Overhead reach
Arm at 104°



C · Side-lying
Arm supported

Removing bone did not beat placebo surgery



CSAW, 313 patients; Oxford Shoulder Score 0–48, higher is better. Decompression vs placebo −1.3 points (95% CI −3.9 to 1.3). Beard et al. (2018).

Decision pathway

1. **EXPLAIN**
   Subacromial pain is a clinical diagnosis; reassure that narrowing with arm elevation is normal.
2. **LOAD**
   Specific, progressive exercise is first line; a single injection can be considered if no better by 6–8 weeks.
3. **REVIEW**
   Refer if no improvement by 12 weeks; surgery only after six months of non-surgical care.

NOT RECOMMENDED

Decompression surgery as first-line treatment; therapeutic ultrasound; repeated injections.

SEEK ASSESSMENT IF

Suspected fracture or dislocation, signs of infection, a lump or swelling, several inflamed joints, or no improvement by 12 weeks.

REFERENCES (APA 7)

Beard, D. J., Rees, J. L., Cook, J. A., Rombach, I., Cooper, C., Merritt, N., Shirkey, B. A., Donovan, J. L., Gwilym, S., Savulescu, J., Moser, J., Gray, A., Jepson, M., Tracey, I., Judge, A., Wartolowska, K., Carr, A. J., Ahrens, P., Baldwick, C., Brinsden, M., … CSAW Study Group. (2018). Arthroscopic subacromial decompression for subacromial shoulder pain (CSAW): A multicentre, pragmatic, parallel group, placebo-controlled, three-group, randomised surgical trial. *The Lancet, 391*(10118), 329–338. https://doi.org/10.1016/S0140-6736(17)32457-1

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Graichen, H., Bonel, H., Stammberger, T., Englmeier, K.-H., Reiser, M., & Eckstein, F. (1999). Subacromial space width changes during abduction and rotation: A 3-D MR imaging study. *Surgical and Radiologic Anatomy, 21*(1), 59–64. https://doi.org/10.1007/BF01635055

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Reinold, M. M., Macrina, L. C., Wilk, K. E., Fleisig, G. S., Dun, S., Barrentine, S. W., Ellerbusch, M. T., & Andrews, J. R. (2007). Electromyographic analysis of the supraspinatus and deltoid muscles during 3 common rehabilitation exercises. *Journal of Athletic Training, 42*(4), 464–469.

Steuri, R., Sattelmayer, M., Elsig, S., Kolly, C., Tal, A., Taeymans, J., & Hilfiker, R. (2017). Effectiveness of conservative interventions including exercise, manual therapy and medical management in adults with shoulder impingement: A systematic review and meta-analysis of RCTs. *British Journal of Sports Medicine, 51*(18), 1340–1347. https://doi.org/10.1136/bjsports-2016-096515

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

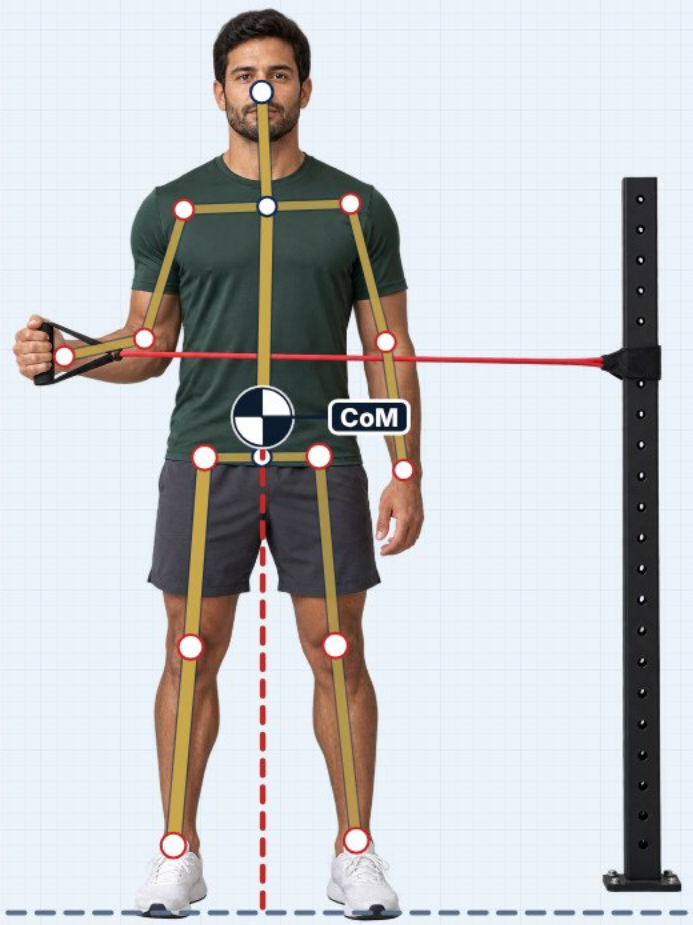
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TENDINOPATHY: HOW LOAD, NOT REST, GUIDES RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

A · BAND ROTATION, FRONT



Start where the shoulder is calm

- Elbow bent and held at the side, the forearm turns outwards against a band: the upper arm stays down, so the lever on the shoulder is short and the load easy to dose.
- In a double-blind trial, progressive high-load and low-load programmes improved function by similar amounts at 12 weeks; consistent progression mattered more than intensity.

Heavy or light: both improved



RoCTEx, 100 patients; adjusted difference −1.37 points (95% CI −6.72 to 3.99, p = 0.61). Ingwersen et al. (2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton and CoM only; the forearm points towards the camera, so no elbow angle is quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

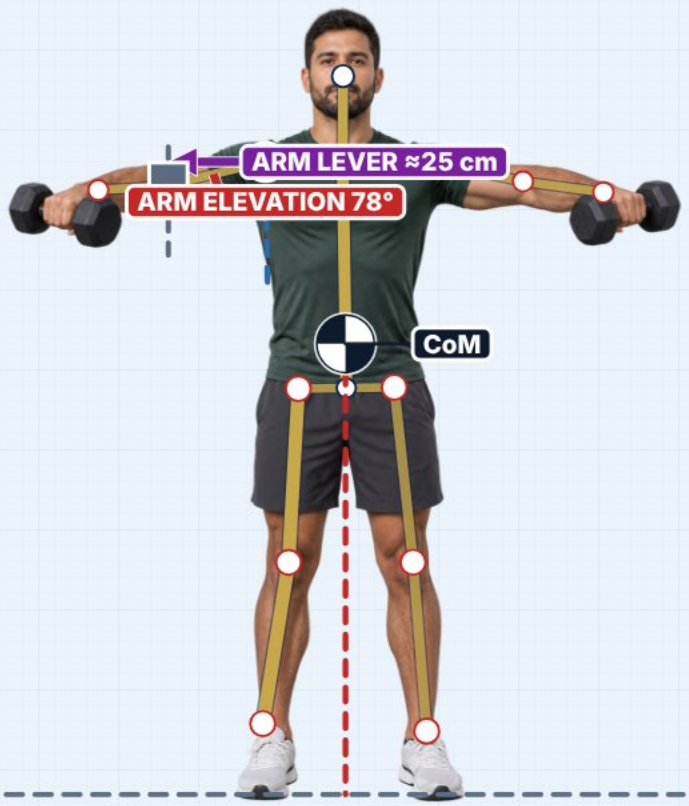
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TENDINOPATHY: HOW LOAD, NOT REST, GUIDES RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

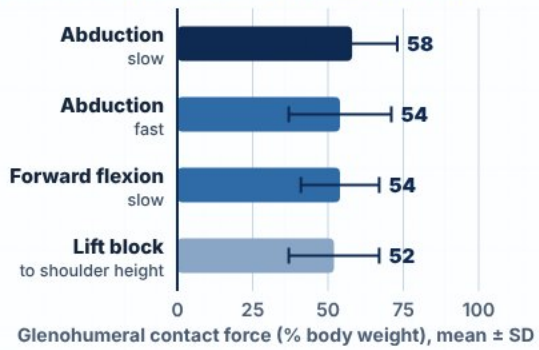
B · LATERAL RAISE, FRONT



Lateral raise: three dials to turn

- Arms out to **78°**: each arm's own weight acts **≈25 cm** from the joint, **≈8 N·m**, before the dumbbell adds its load at the hand.
- Range, lever length (a bent elbow) and external weight are the three dials for grading this exercise as the tendon settles.

The unloaded arm already loads the joint



25 adults; musculoskeletal model estimates, not implant measurements. Klemt et al. (2018).

Key point: progressive resistance and motor-control exercise carries the guideline's strongest grade (A) for this condition.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Dumbbell weight is not included. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

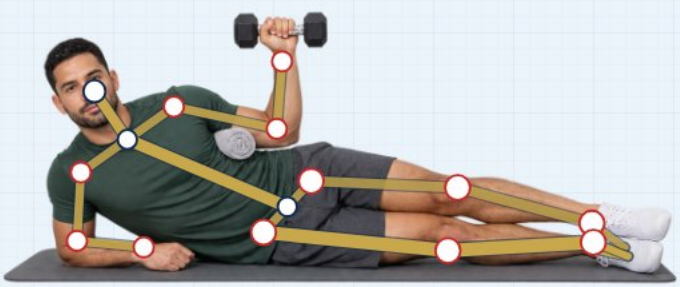
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TENDINOPATHY: HOW LOAD, NOT REST, GUIDES RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

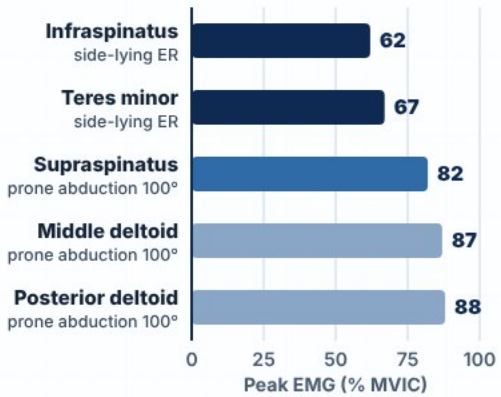
C · SIDE-LYING ROTATION, FRONT



Side-lying: gravity as the weight

- Lying on the side with the elbow on a towel, rotating the dumbbell upwards works against gravity, a simple way to dose the posterior cuff.
- Of seven rotation exercises, side-lying external rotation gave the highest infraspinatus and teres minor activity; prone abduction at 100° recruited more deltoid.

Which exercise works the posterior cuff?



10 healthy participants, seven external-rotation exercises; peak values. Reinold et al. (2004).

Myth: "Rest the tendon until it stops hurting." Exercise beat no-exercise control (SMD −0.94; Steuri et al., 2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in lying positions, so no angles are quoted for this frame. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TENDINOPATHY: HOW LOAD, NOT REST, GUIDES RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Band rotation
Short lever



B · Lateral raise
≈8 N·m per arm



C · Side-lying
Gravity-loaded cuff

Over a year, advice matched a programme



GRASP, 708 adults; SPADI 0–100. Active self-management with graded loading was the common ingredient. Hopewell et al. (2021).

Decision pathway

1. **LOAD**
   Progressive resistance and motor-control exercise is the core treatment, with education.
2. **PROGRESS**
   Turn up range, lever and weight as tolerance improves; return to sport on load tolerance.
3. **REVIEW**
   Seek a specialist opinion after 12 weeks of persistent, severe symptoms.

NOT RECOMMENDED

Initial imaging; therapeutic ultrasound; shockwave for non-calcific tendinopathy.

SEEK ASSESSMENT IF

Sudden loss of the ability to lift the arm after a fall or forceful pull, suspected fracture or dislocation, infection, or a lump.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Hopewell, S., Keene, D. J., Marian, I. R., Dritsaki, M., Heine, P., Cureton, L., Dutton, S. J., Dakin, H., Carr, A., Hamilton, W., Hansen, Z., Jaggi, A., Littlewood, C., Barker, K. L., Gray, A., Lamb, S. E., Bateman, M., Hallett, A., Thompson, H., Willmore, E., … GRASP Trial Group. (2021). Progressive exercise compared with best practice advice, with or without corticosteroid injection, for the treatment of patients with rotator cuff disorders (GRASP): A multicentre, pragmatic, 2 × 2 factorial, randomised controlled trial. *The Lancet, 398*(10298), 416–428. https://doi.org/10.1016/S0140-6736(21)00846-1

Ingwersen, K. G., Jensen, S. L., Sørensen, L., Jørgensen, H. R., Christensen, R., Søgaard, K., & Juul-Kristensen, B. (2017). Three months of progressive high-load versus traditional low-load strength training among patients with rotator cuff tendinopathy: Primary results from the double-blind randomized controlled RoCTEx trial. *Orthopaedic Journal of Sports Medicine, 5*(8), 2325967117723292. https://doi.org/10.1177/2325967117723292

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Reinold, M. M., Wilk, K. E., Fleisig, G. S., Zheng, N., Barrentine, S. W., Chmielewski, T., Cody, R. C., Jameson, G. G., & Andrews, J. R. (2004). Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *Journal of Orthopaedic & Sports Physical Therapy, 34*(7), 385–394. https://doi.org/10.2519/jospt.2004.34.7.385

Steuri, R., Sattelmayer, M., Elsig, S., Kolly, C., Tal, A., Taeymans, J., & Hilfiker, R. (2017). Effectiveness of conservative interventions including exercise, manual therapy and medical management in adults with shoulder impingement: A systematic review and meta-analysis of RCTs. *British Journal of Sports Medicine, 51*(18), 1340–1347. https://doi.org/10.1136/bjsports-2016-096515

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

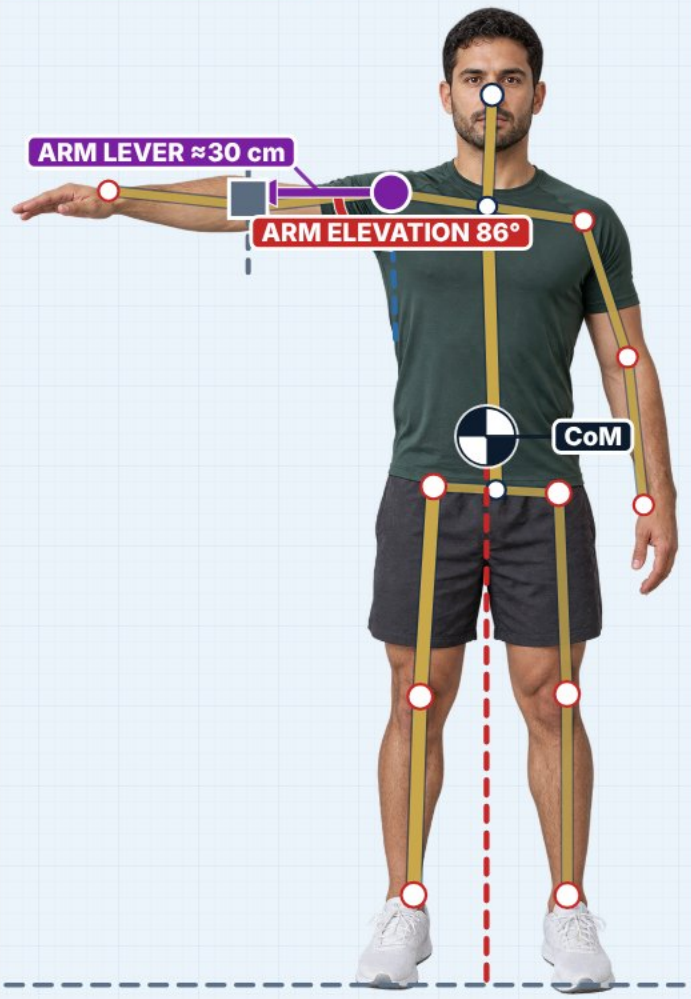
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEAR: DOES EVERY TEAR NEED SURGERY?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

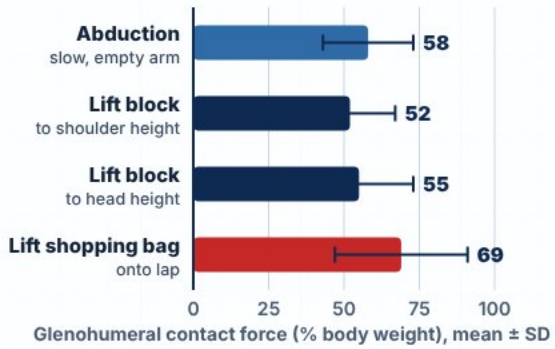
A · SIDE RAISE, FRONT



A weak cuff meets a long lever

- Arm raised **86°** out to the side with a straight elbow: the arm's weight acts **≈30 cm** from the joint, **≈10 N·m** for the cuff and deltoid to hold.
- With a tear, this position can feel effortful or weak. Everyday lifts put roughly half of body weight or more through the joint, the demand strengthening targets.

Everyday lifts load the joint



25 adults; musculoskeletal model estimates, not implant measurements. Klemt et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

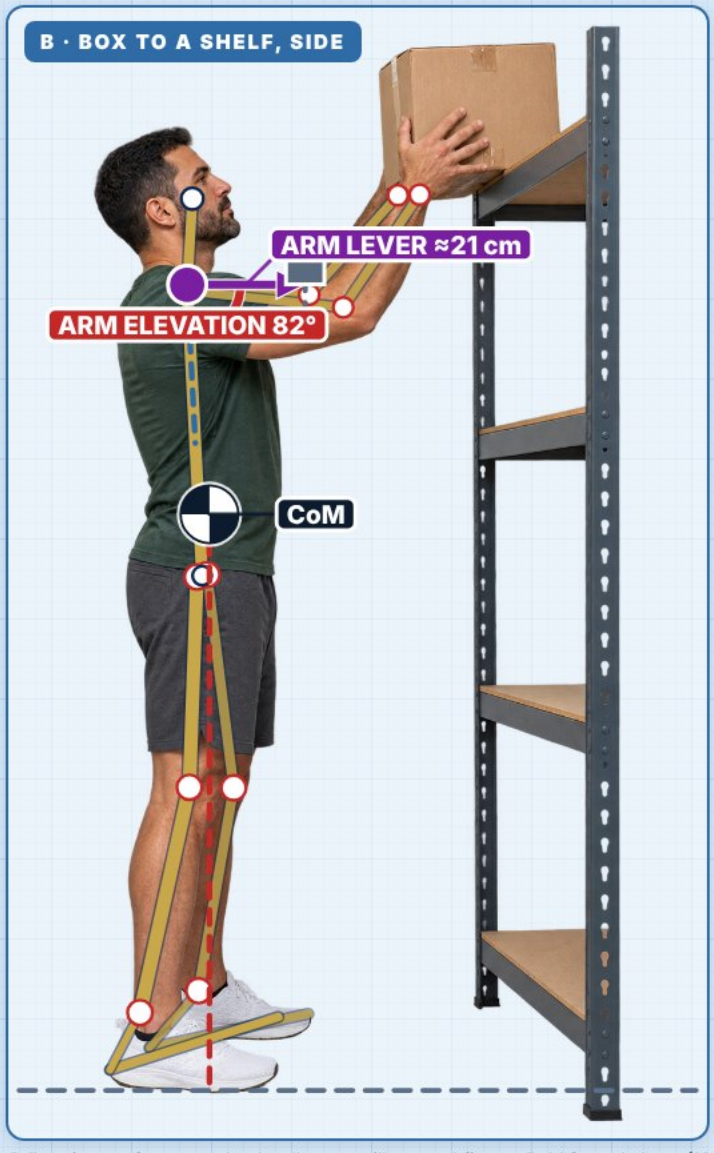
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEAR: DOES EVERY TEAR NEED SURGERY?

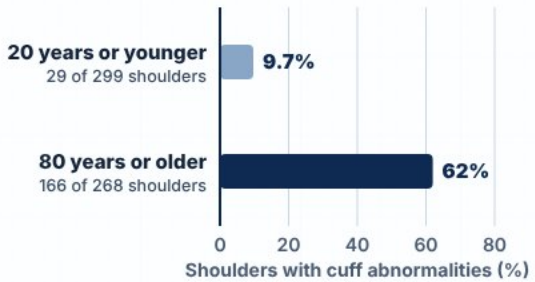
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Lifting to a shelf

- Box lifted towards head height, upper arm at **82°**: lever **≈21 cm**, **≈7 N·m** from the arm alone, before the box adds its weight at the hands.
- Cuff tears become common with age. In 452 people with atraumatic full-thickness tears, physiotherapy was effective in about 75% at two years.

Cuff changes rise with age



30 studies, 6112 shoulders; odds ratio oldest vs youngest 15 (95% CI 9.6–24). Teunis et al. (2014). Cohort: Kuhn et al. (2013).

Key point: fewer than 25% chose surgery, usually between 6 and 12 weeks; those improving by 12 weeks tended to keep improving.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Box weight is not included. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

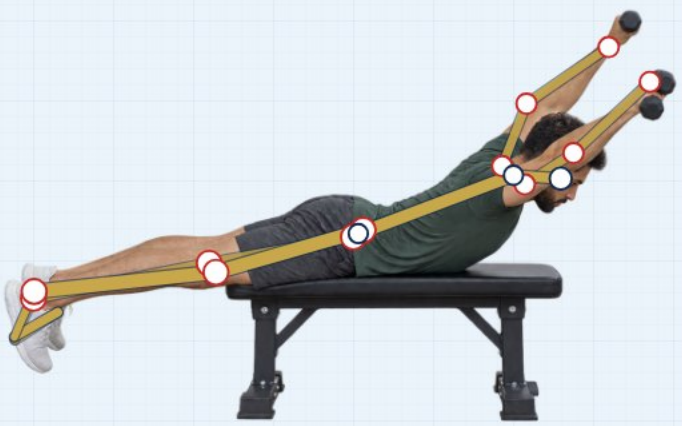
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEAR: DOES EVERY TEAR NEED SURGERY?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

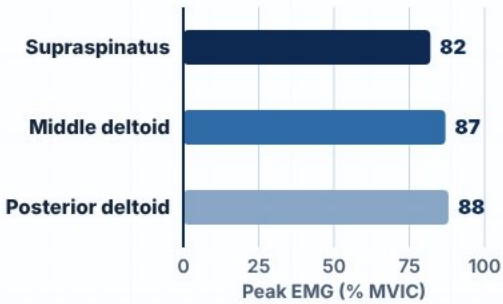
C · PRONE Y RAISE, SIDE



Prone raises: a later-stage step

- Face down on a bench, arms forward in a Y with very light dumbbells: the arms are raised against gravity at long levers, a demanding position for the cuff.
- A close relative, prone horizontal abduction at 100°, strongly recruited supraspinatus and the deltoid, so it follows side-lying and band work.

High activity in a prone overhead raise



10 healthy participants; prone horizontal abduction at 100° with full external rotation, peak values. Reinold et al. (2004).

Myth: "A torn tendon cannot work without surgery." One-year scores were similar with physiotherapy alone and with repair.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in lying positions, so no angles are quoted for this frame. Educational, not diagnostic.

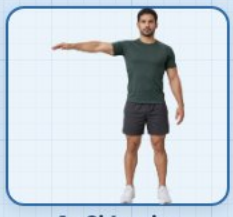
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEAR: DOES EVERY TEAR NEED SURGERY?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Side raise
≈10 N·m

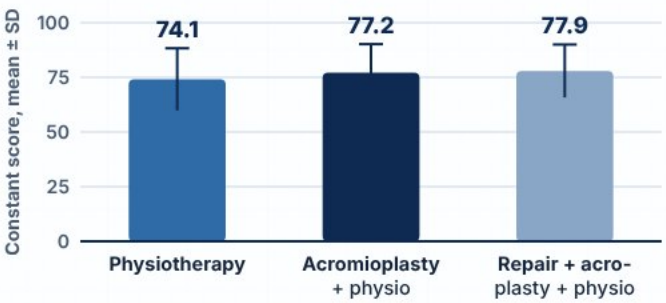


B · Box to shelf
Lever ≈21 cm



C · Prone Y
Later-stage exercise

Non-traumatic tears: one-year outcome



167 shoulders, mean age 65; similar improvement in all groups (p = 0.34). Kukkonen et al. (2014).

Decision pathway

1. **TRY PHYSIOTHERAPY**
   A structured programme is a reasonable first option for atraumatic tears.
2. **REVIEW AT 12 WEEKS**
   Refer if there is no improvement by 12 weeks of non-operative care.
3. **DISCUSS SURGERY**
   Discuss repair if symptoms persist or a tear enlarges; without surgery, tears may grow over 5–10 years.

NOT RECOMMENDED

Multiple steroid injections; prolotherapy for full-thickness tears.

SEEK ASSESSMENT IF

Sudden weakness after a fall or dislocation, suspected fracture, infection, a lump, or several inflamed joints.

REFERENCES (APA 7)

American Academy of Orthopaedic Surgeons. (2025). Management of rotator cuff injuries: Evidence-based clinical practice guideline (adopted 18 August 2025). https://www.aaos.org/rccpg2025 (guideline; no DOI assigned)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Kuhn, J. E., Dunn, W. R., Sanders, R., An, Q., Baumgarten, K. M., Bishop, J. Y., Brophy, R. H., Carey, J. L., Holloway, B. G., Jones, G. L., Ma, C. B., Marx, R. G., McCarty, E. C., Poddar, S. K., Smith, M. V., Spencer, E. E., Vidal, A. F., Wolf, B. R., & Wright, R. W. (2013). Effectiveness of physical therapy in treating atraumatic full-thickness rotator cuff tears: A multicenter prospective cohort study. *Journal of Shoulder and Elbow Surgery, 22*(10), 1371–1379. https://doi.org/10.1016/j.jse.2013.01.026

Kukkonen, J., Joukainen, A., Lehtinen, J., Mattila, K. T., Tuominen, E. K. J., Kauko, T., & Äärimaa, V. (2014). Treatment of non-traumatic rotator cuff tears: A randomised controlled trial with one-year clinical results. The Bone & Joint Journal, 96-B(1), 75–81. https://doi.org/10.1302/0301-620X.96B1.32168

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Reinold, M. M., Wilk, K. E., Fleisig, G. S., Zheng, N., Barrentine, S. W., Chmielewski, T., Cody, R. C., Jameson, G. G., & Andrews, J. R. (2004). Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *Journal of Orthopaedic & Sports Physical Therapy, 34*(7), 385–394. https://doi.org/10.2519/jospt.2004.34.7.385

Teunis, T., Lubberts, B., Reilly, B. T., & Ring, D. (2014). A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age. *Journal of Shoulder and Elbow Surgery, 23*(12), 1913–1921. https://doi.org/10.1016/j.jse.2014.08.001

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

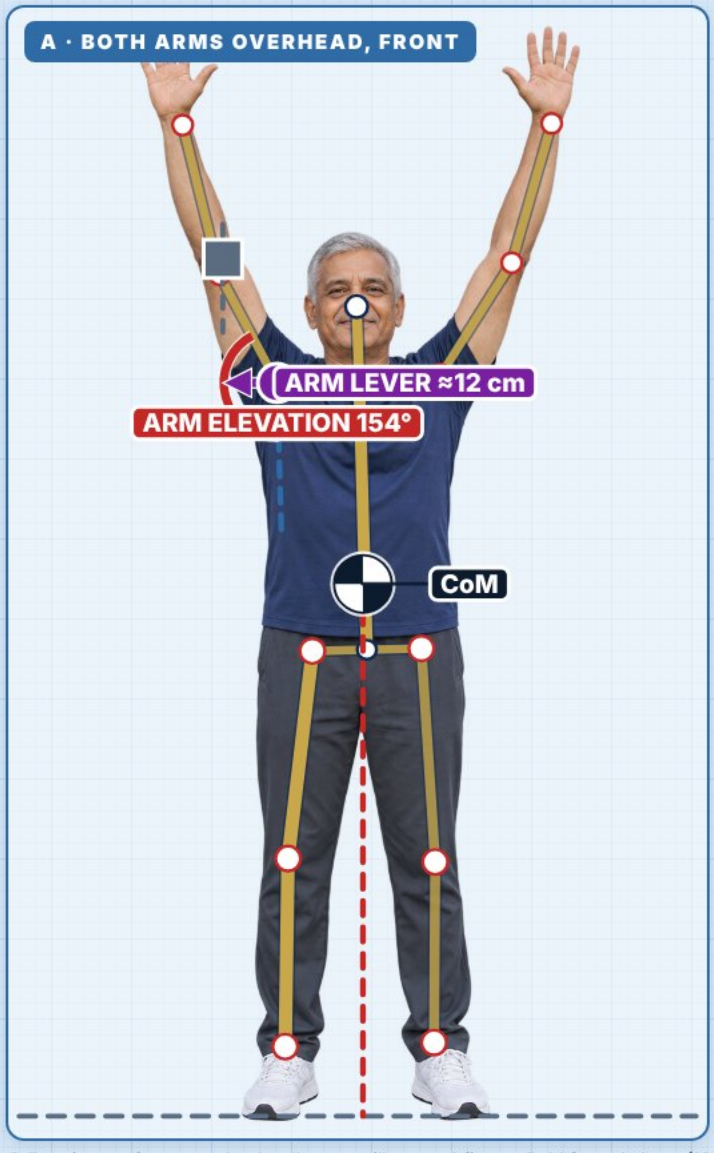
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEARS ON MRI: WHY MANY PAINLESS SHOULDERS HAVE THEM TOO

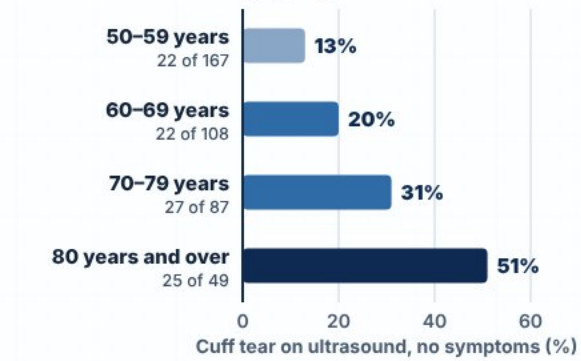
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A comfortable shoulder can still show a tear

- Both arms raised to about **154°** with a relaxed face: near vertical, each arm's lever is short (**≈12 cm**, **≈4 N·m**).
- In 411 pain-free volunteers aged 50 and over, 23% had a cuff tear on ultrasound; by the 80s it was about half.

Painless shoulders, by age



411 asymptomatic volunteers, prospective clinical and ultrasound study. Tempelhof et al. (1999).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

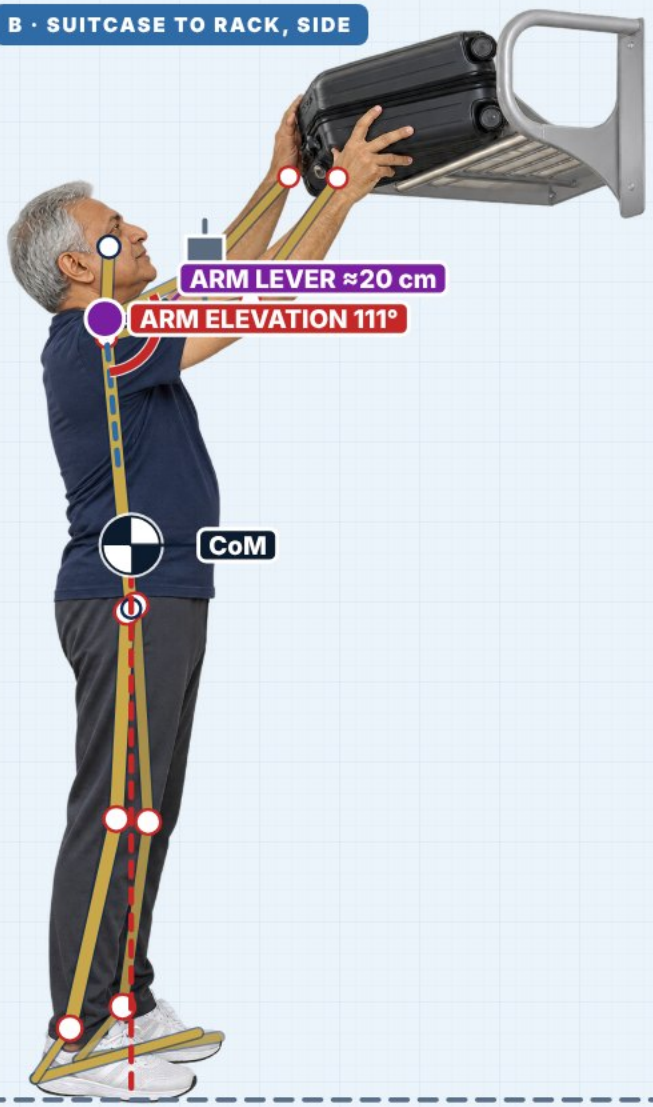
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEARS ON MRI: WHY MANY PAINLESS SHOULDERS HAVE THEM TOO

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

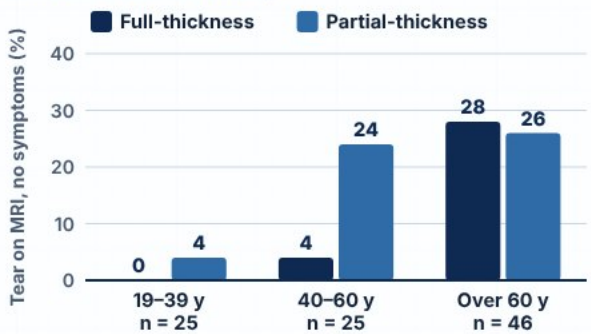
B · SUITCASE TO RACK, SIDE



Lifting overhead with an older shoulder

- Suitcase lifted towards the rack, arm at **111°**: lever **≈20 cm**, **≈7 N·m** from the arm alone, before the case adds its weight.
- On MRI of 96 people without pain, 34% had a tear (15% full, 20% partial thickness); in those over 60, 54% did.

MRI tears rise with age



96 asymptomatic adults; rise with age $p < 0.001$ (full) and $p < 0.05$ (partial). Sher et al. (1995).

Myth: "My MRI shows a tear, so the tear is causing my pain." Tears are common in pain-free shoulders; the scan must match the examination.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Suitcase weight is not included. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEARS ON MRI: WHY MANY PAINLESS SHOULDERS HAVE THEM TOO

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

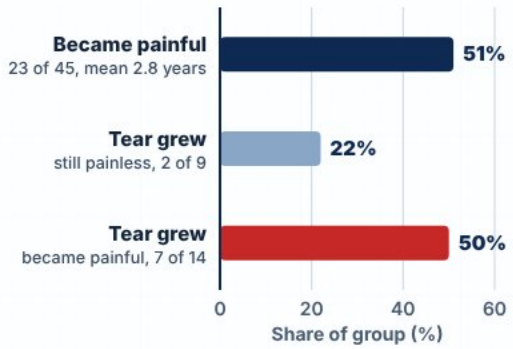
C · WALL PUSH-UP, SIDE



Keep the shoulder working

- Wall push-up, body leaning about **25°** from vertical: only part of body weight passes through the hands, a gentle closed-chain way to load the shoulder.
- Painless tears were followed for about three years: half became painful, and new pain was linked with tear enlargement in some people.

What happens to a painless tear?



45 patients with sonographic asymptomatic tears; growth among 23 re-scanned. 7 of 14 is arithmetic from published counts. Yamaguchi et al. (2001).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from pose landmarks: shoulder–hip line relative to vertical. Educational, not diagnostic.

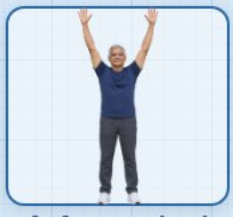
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROTATOR CUFF TEARS ON MRI: WHY MANY PAINLESS SHOULDERS HAVE THEM TOO

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Arms overhead
Lever ≈12 cm

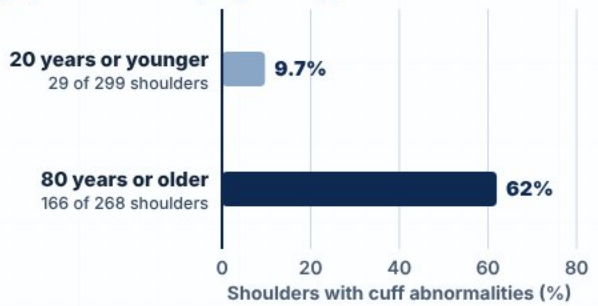


B · Suitcase lift
≈7 N·m



C · Wall push-up
Lean ≈25°

Age, more than symptoms, predicts the scan



30 studies, 6112 shoulders; similar rise regardless of symptoms; odds ratio 15 (95% CI 9.6–24). Teunis et al. (2014).

Decision pathway

1. **EXAMINE FIRST**
   Subacromial pain is a clinical diagnosis; imaging is not needed to start treatment.
2. **MATCH**
   Interpret any scan alongside the examination; a tear may be a normal age change.
3. **IMAGE IF NEEDED**
   After 12 weeks without progress, ultrasound is preferred; X-ray after trauma or with red flags.

NOT RECOMMENDED

Imaging at the first visit; routine MRI for suspected tendinopathy.

SEEK ASSESSMENT IF

Sudden painful loss of arm lifting after trauma, suspected fracture or dislocation, infection, a mass, or several inflamed joints.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Sher, J. S., Uribe, J. W., Posada, A., Murphy, B. J., & Zlatkin, M. B. (1995). Abnormal findings on magnetic resonance images of asymptomatic shoulders. *Journal of Bone and Joint Surgery, American Volume, 77*(1), 10–15. https://doi.org/10.2106/00004623-199501000-00002

Tempelhof, S., Rupp, S., & Seil, R. (1999). Age-related prevalence of rotator cuff tears in asymptomatic shoulders. *Journal of Shoulder and Elbow Surgery, 8*(4), 296–299. https://doi.org/10.1016/S1058-2746(99)90148-9

Teunis, T., Lubberts, B., Reilly, B. T., & Ring, D. (2014). A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age. *Journal of Shoulder and Elbow Surgery, 23*(12), 1913–1921. https://doi.org/10.1016/j.jse.2014.08.001

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Yamaguchi, K., Tetro, A. M., Blam, O., Evanoff, B. A., Teefey, S. A., & Middleton, W. D. (2001). Natural history of asymptomatic rotator cuff tears: A longitudinal analysis of asymptomatic tears detected sonographically. *Journal of Shoulder and Elbow Surgery, 10*(3), 199–203. https://doi.org/10.1067/mse.2001.113086

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

MMSx Authority
APPLIED BIOMECHANICS LAB

DOI 10.5281/zenodo.23735725

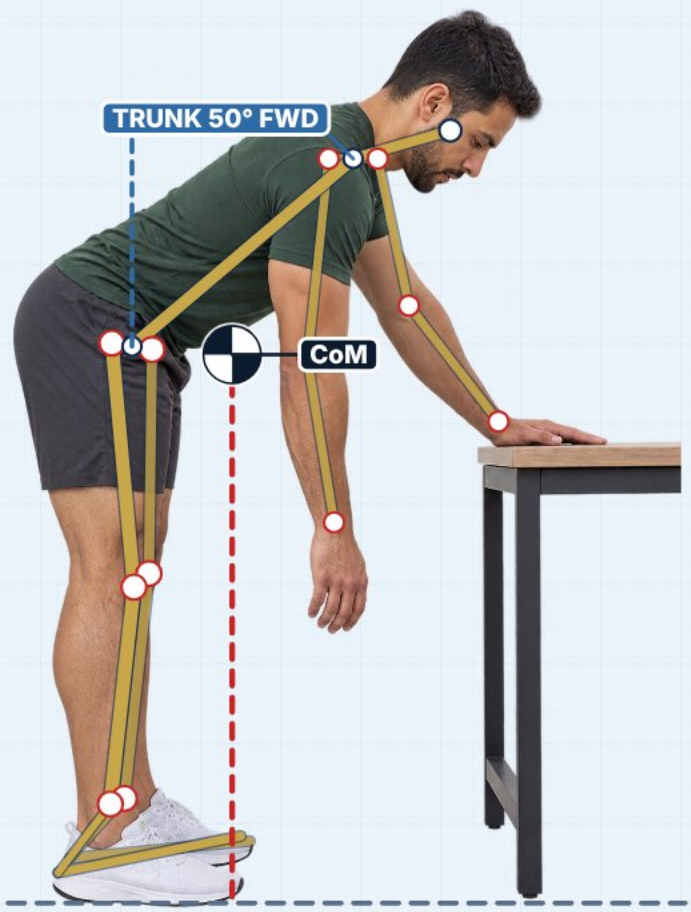
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER: THE FREEZING, FROZEN AND THAWING PHASES EXPLAINED

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

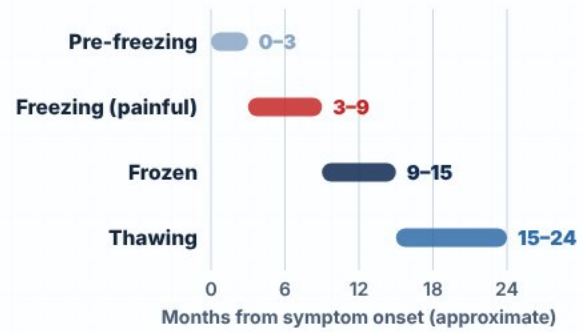
A · PENDULUM SWING, SIDE



Early on: pain leads, stiffness follows

- Leaning forward ≈**50°** with the other hand on the table lets the painful arm hang and swing gently, moving the joint without the muscles having to lift it.
- Frozen shoulder is a condition of the joint capsule: gradual pain, then marked loss of active and passive motion, especially rotating outwards.

The classic stages, as a guide



Stages from the APTA guideline, which grades the condition as a continuum (Grade C), not a fixed timetable. Kelley et al. (2013).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from pose landmarks: shoulder–hip line relative to vertical. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

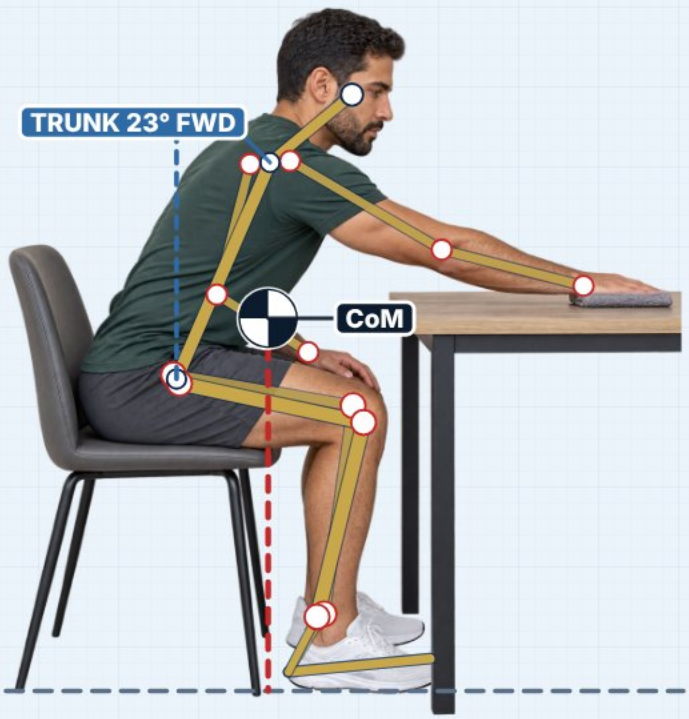
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER: THE FREEZING, FROZEN AND THAWING PHASES EXPLAINED

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

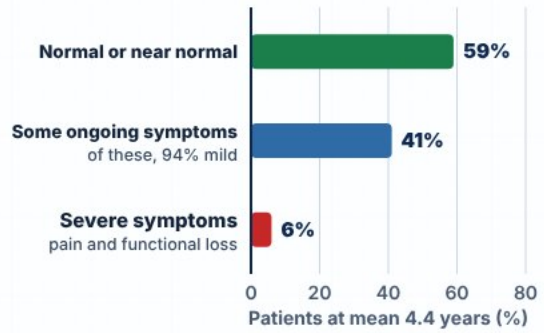
B · TABLE SLIDE, SIDE



The frozen phase: keep range moving

- Seated, the hand slides forward on a towel while the trunk leans ≈**23°**: the table carries the arm's weight, so the shoulder gains elevation with little muscle load.
- In 223 patients followed for a mean of 4.4 years, most ended with a good shoulder, but four in ten kept some symptoms, mostly mild.

Long-term outcome



223 patients (269 shoulders), follow-up 2–20 years; worst symptoms at onset predicted the worst outcome. Hand et al. (2008).

Myth: "It always clears up by itself within two years." At a mean of 4.4 years, 41% still had some symptoms.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from pose landmarks: shoulder–hip line relative to vertical. Educational, not diagnostic.

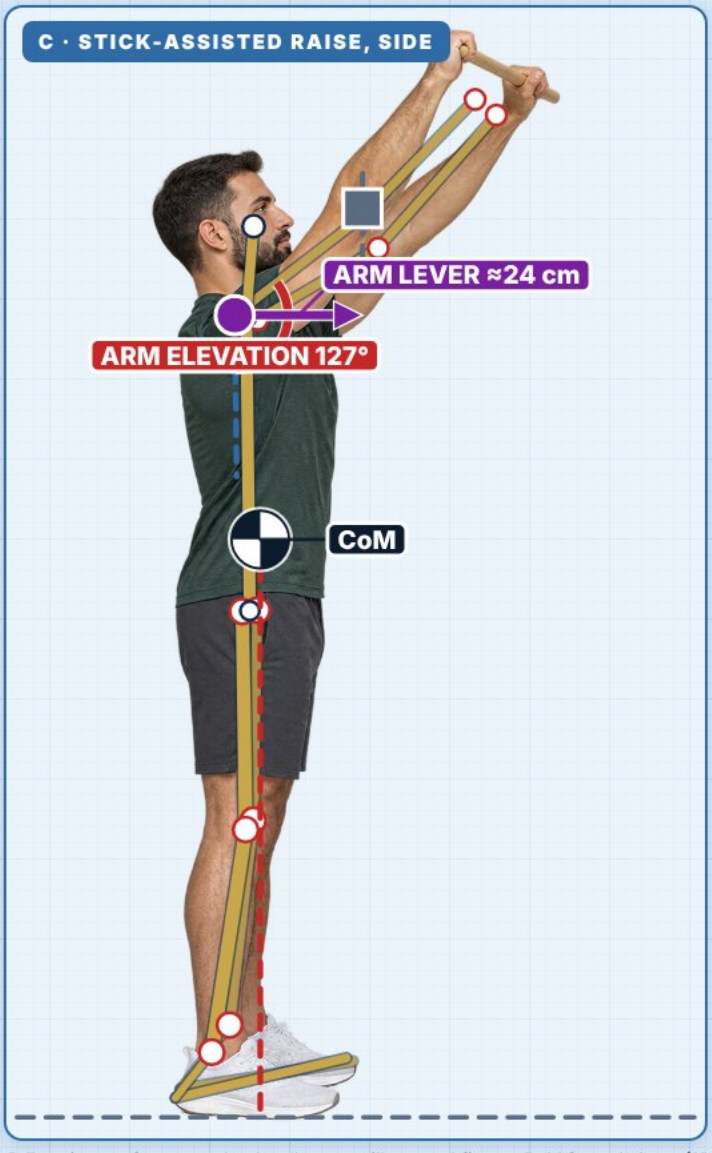
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER: THE FREEZING, FROZEN AND THAWING PHASES EXPLAINED

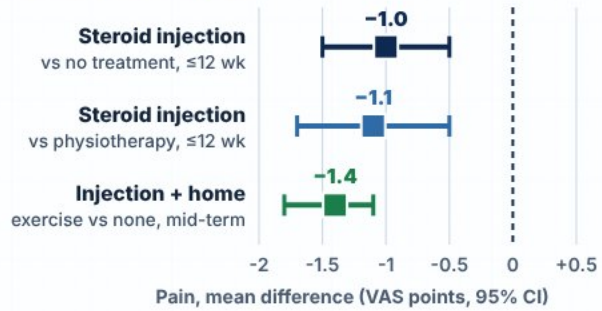
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Thawing: the good arm helps

- Both hands on a stick, the left arm helps lift the right to ≈**127°**. Unaided, the arm's weight would act ≈**24 cm** from the joint (≈**8 N·m**); the stick shares that load.
- An early joint injection combined with home exercise was linked with the best short- and mid-term pain results in shoulders stiff for under a year.

What helps early on?



Network meta-analysis, 65 studies, 4097 participants; negative favours the injection. Challoumas et al. (2020).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Unassisted value; the stick reduces the real moment. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER: THE FREEZING, FROZEN AND THAWING PHASES EXPLAINED

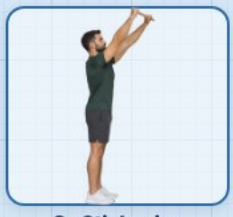
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Pendulum
Trunk ≈50°

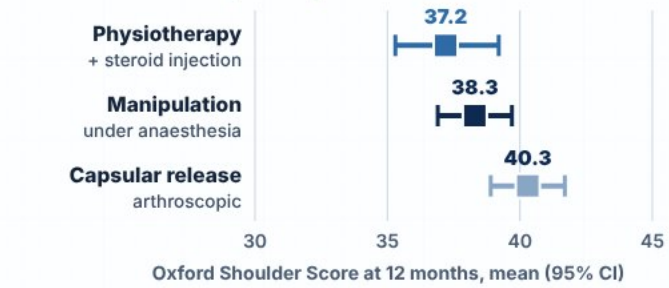


B · Table slide
Table carries the arm



C · Stick raise
≈127°, assisted

Three treatments, no important difference



UK FROST, 503 adults; no difference reached the 4–5 point target. Release: 8 serious adverse events, manipulation 2. Rangan et al. (2020).

Decision pathway

1. **EXPLAIN**
   Describe the natural course; match stretching intensity to how irritable the shoulder is.
2. **INJECT + MOVE**
   A joint steroid injection with mobility and stretching exercises has the strongest grade.
3. **REVIEW**
   X-ray with severe pain or stiffness; consider other diagnoses if the picture does not fit.

NOT RECOMMENDED

Forcing painful end-range stretches in an irritable shoulder.

SEEK ASSESSMENT IF

Weight loss, fever, a history of cancer, swollen glands, generalised joint pain, or a bony swelling or mass.

REFERENCES (APA 7)

Challoumas, D., Biddle, M., McLean, M., & Millar, N. L. (2020). Comparison of treatments for frozen shoulder: A systematic review and meta-analysis. *JAMA Network Open, 3*(12), e2029581. https://doi.org/10.1001/jamanetworkopen.2020.29581

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hand, C., Clipsham, K., Rees, J. L., & Carr, A. J. (2008). Long-term outcome of frozen shoulder. *Journal of Shoulder and Elbow Surgery, 17*(2), 231–236. https://doi.org/10.1016/j.jse.2007.05.009

Kelley, M. J., Shaffer, M. A., Kuhn, J. E., Michener, L. A., Seitz, A. L., Uhl, T. L., Godges, J. J., & McClure, P. W. (2013). Shoulder pain and mobility deficits: Adhesive capsulitis. Clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy, 43*(5), A1–A31. https://doi.org/10.2519/jospt.2013.0302

Mitchell, C., Adebajo, A., Hay, E., & Carr, A. (2005). Shoulder pain: Diagnosis and management in primary care. *BMJ, 331*(7525), 1124–1128. https://doi.org/10.1136/bmj.331.7525.1124

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Rangan, A., Brealey, S. D., Keding, A., Corbacho, B., Northgraves, M., Kottam, L., Goodchild, L., Srikesavan, C., Rex, S., Charalambous, C. P., Hanchard, N., Armstrong, A., Brooksbank, A., Carr, A., Cooper, C., Dias, J., Donnelly, I., Hewitt, C., Lamb, S. E., McDaid, C., … Torgerson, D. (2020). Management of adults with primary frozen shoulder in secondary care (UK FROST): A multicentre, pragmatic, three-arm, superiority randomised clinical trial. *The Lancet, 396*(10256), 977–989. https://doi.org/10.1016/S0140-6736(20)31965-6

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER AND DIABETES: WHY STIFFNESS BEHAVES DIFFERENTLY

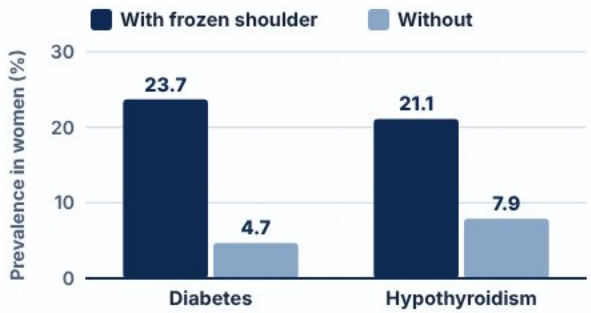
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Behind the back: the stiff direction

- Towel behind the back: the top arm is raised ≈**133°** and pulls the lower hand gently up the spine; the shoulder line tilts ≈**14°** as the body adjusts.
- Diabetes and thyroid disease are recognised risk factors (Grade B); screening is reasonable when stiffness has no clear cause.

Endocrine links in one cohort



Cohort as reported in the APTA guideline (secondary reporting). Kelley et al. (2013).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation of the top arm and shoulder line from pose landmarks in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

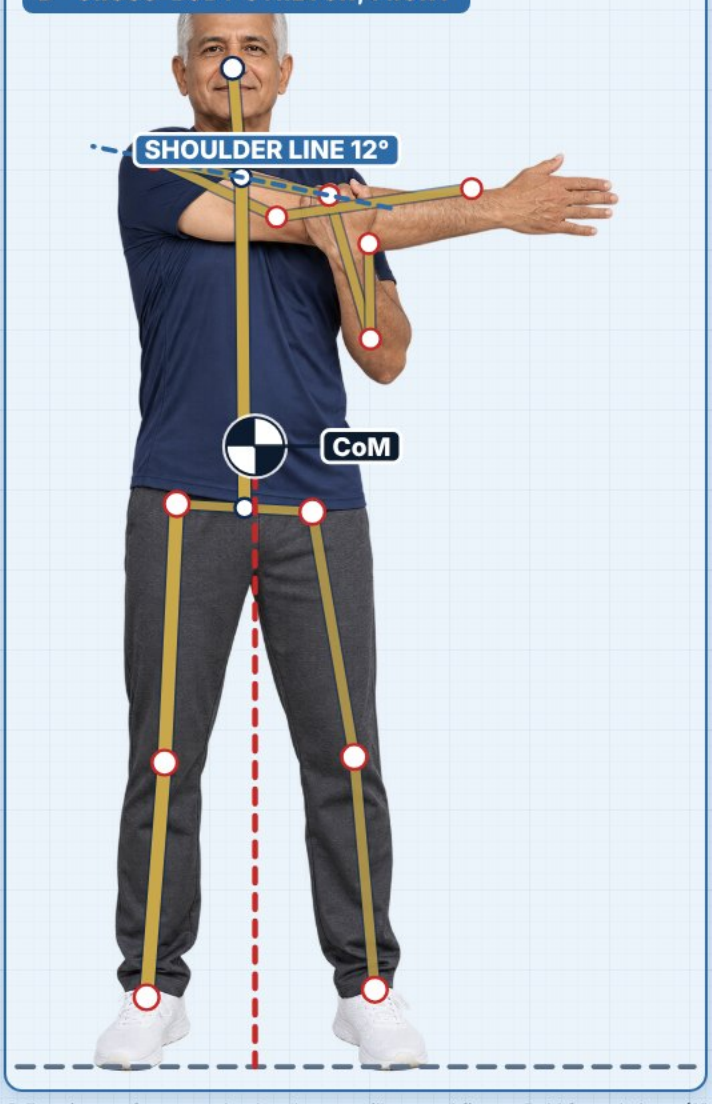
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER AND DIABETES: WHY STIFFNESS BEHAVES DIFFERENTLY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

B · CROSS-BODY STRETCH, FRONT



Across the body: gentle, not forced

- The left hand draws the right arm across the chest; the shoulder line tilts ≈**12°**, a sign the trunk is helping. Intensity should match how irritable the shoulder is.
- About 13% of people with diabetes had frozen shoulder, and 30% of people with frozen shoulder had diabetes.

How common, with and without diabetes



Meta-analysis of 18 studies: Zreik et al. (2016). General-population range: Kelley et al. (2013).

Myth: "Diabetic frozen shoulder will not respond to exercise." The guideline supports stretching dosed to irritability for all patients.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER AND DIABETES: WHY STIFFNESS BEHAVES DIFFERENTLY

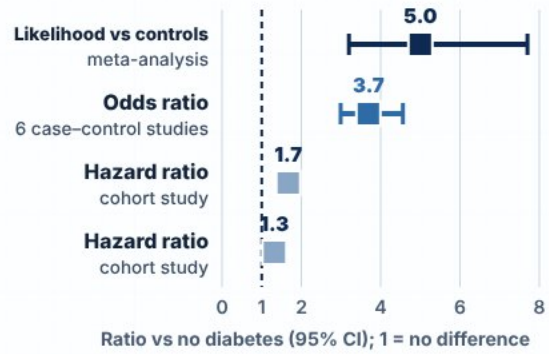
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Rotating outwards with help

- Elbows bent at the sides, the left hand pushes the stick so the right forearm turns outwards: external rotation is usually the most restricted direction in frozen shoulder.
- Every estimate places diabetes above the no-difference line, but this is an association; most included studies had a high risk of bias.

Diabetes and the risk of frozen shoulder



Exact: OR 3.69, HR 1.32 and 1.67. Zreik et al. (2016); Dyer et al. (2023), who rated risk of bias high in seven of eight studies.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton and CoM only; the forearms point towards the camera, so no elbow angle is quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

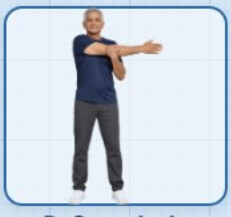
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FROZEN SHOULDER AND DIABETES: WHY STIFFNESS BEHAVES DIFFERENTLY

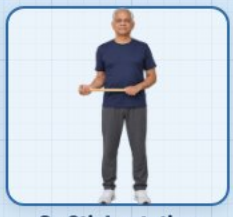
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Towel stretch
Top arm ≈133°

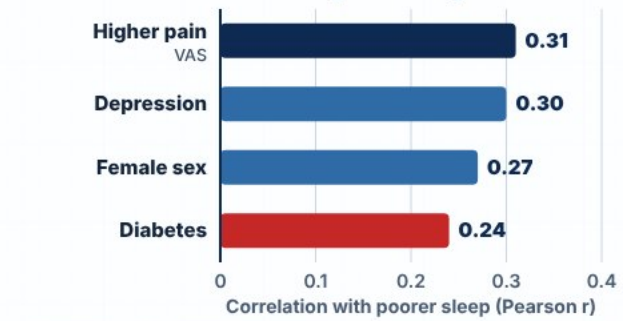


B · Cross-body
Shoulder line ≈12°



C · Stick rotation
Outward rotation

Diabetes also tracks with poor sleep



117 people with cuff tears; weak correlations, not causal. Khazzam et al. (2018).

Decision pathway

1. **SCREEN**
   Ask about diabetes and thyroid disease when stiffness has no clear cause.
2. **INJECT + STRETCH**
   A joint steroid injection with mobility and stretching exercises; dose stretching to irritability.
3. **EXPECT LONGER**
   Symptoms may last longer with diabetes; review progress rather than a fixed timetable.

NOT RECOMMENDED

Forcing painful end-range stretching in an irritable shoulder.

SEEK ASSESSMENT IF

Weight loss, fever, a history of cancer, swollen glands, generalised joint pain, a bony mass, or unexplained new stiffness.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Dyer, B. P., Rathod-Mistry, T., Burton, C., van der Windt, D., & Bucknall, M. (2023). Diabetes as a risk factor for the onset of frozen shoulder: A systematic review and meta-analysis. *BMJ Open, 13*(1), e062377. https://doi.org/10.1136/bmjopen-2022-062377

Kelley, M. J., Shaffer, M. A., Kuhn, J. E., Michener, L. A., Seitz, A. L., Uhl, T. L., Godges, J. J., & McClure, P. W. (2013). Shoulder pain and mobility deficits: Adhesive capsulitis. Clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy, 43*(5), A1–A31. https://doi.org/10.2519/jospt.2013.0302

Khazzam, M. S., Mulligan, E. P., Brunette-Christiansen, M., & Shirley, Z. (2018). Sleep quality in patients with rotator cuff disease. *Journal of the American Academy of Orthopaedic Surgeons, 26*(6), 215–222. https://doi.org/10.5435/JAAOS-D-16-00547

Mitchell, C., Adebajo, A., Hay, E., & Carr, A. (2005). Shoulder pain: Diagnosis and management in primary care. *BMJ, 331*(7525), 1124–1128. https://doi.org/10.1136/bmj.331.7525.1124

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Zreik, N. H., Malik, R. A., & Charalambous, C. P. (2016). Adhesive capsulitis of the shoulder and diabetes: A meta-analysis of prevalence. *Muscles, Ligaments and Tendons Journal, 6*(1), 26–34. https://doi.org/10.11138/mltj/2016.6.1.026

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

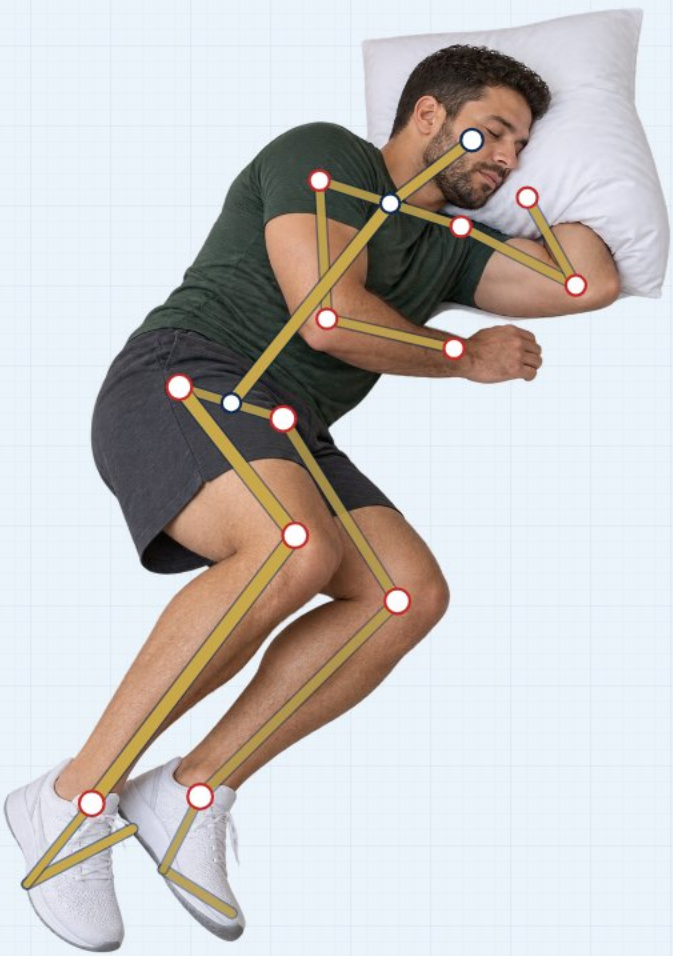
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AT NIGHT: SLEEP POSITIONS AND SYMPTOMS WORTH CHECKING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

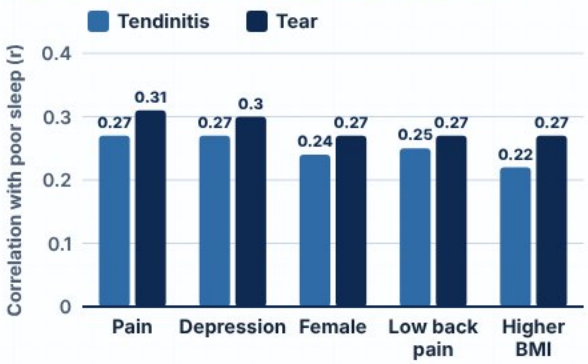
A · ON THE PAINFUL SIDE, FRONT



Lying on the painful shoulder

- Side-lying on the right puts body weight through that shoulder; workers with left-shoulder pain were about twice as likely to sleep on the right, away from the pain.
- Night pain was reported by 91% of 391 people with rotator cuff disease, and poor sleep tracked mood, sex, other pain and BMI as well as shoulder pain.

Poor sleep is not only about the shoulder



391 patients (274 tendinitis, 117 tears), mean age 57; weak correlations, not causes. Khazzam et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose landmarks are less reliable in lying positions, so no angles or levers are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AT NIGHT: SLEEP POSITIONS AND SYMPTOMS WORTH CHECKING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

B · ON THE BACK, SIDE



On the back, arm supported

- Lying on the back with a pillow under the forearm and elbow: in a laboratory study, subacromial pressure was lower in supine positions than in side-lying or prone ones.
- This is a comfort measure, not a cure; night pain usually eases as the shoulder itself improves.

Sleep recovers as the shoulder recovers



326 patients after cuff repair; 89% reported disturbed sleep beforehand. Dolan et al. (2022). Pressure study: Werner et al. (2010).

Key point: treat the underlying condition: exercise is core, with short-term pain relief or a single injection if needed.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose landmarks are less reliable in lying positions, so no angles or levers are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

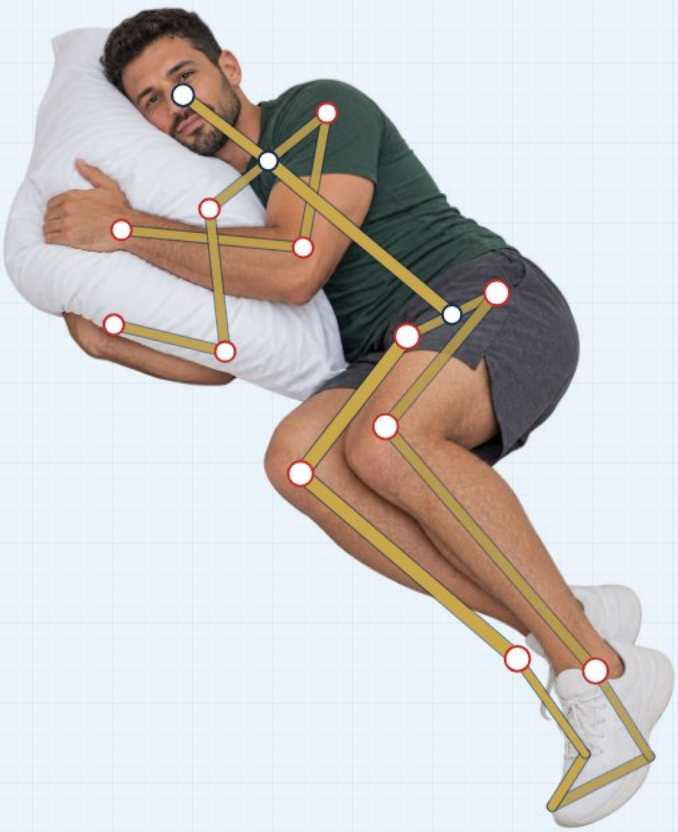
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AT NIGHT: SLEEP POSITIONS AND SYMPTOMS WORTH CHECKING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

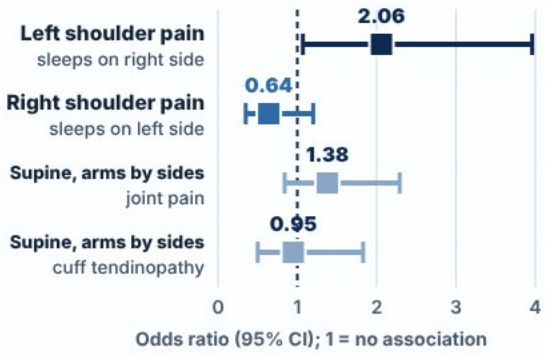
C · ON THE OTHER SIDE, FRONT



On the other side, hugging a pillow

- Lying on the pain-free side with the painful arm resting on a pillow keeps that arm from dropping across the chest.
- In 761 workers, people tended to avoid lying on the painful side, and no sleep posture was clearly linked with rotator cuff tendinopathy.

Sleep posture and shoulder pain



761 workers, cross-sectional. Holdaway et al. (2018). Cross-sectional: posture may follow pain rather than cause it.

Myth: "Sleeping on my side gave me this shoulder problem." No posture was clearly associated with cuff tendinopathy.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose landmarks are less reliable in lying positions, so no angles or levers are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AT NIGHT: SLEEP POSITIONS AND SYMPTOMS WORTH CHECKING

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Painful side
Weight on the shoulder

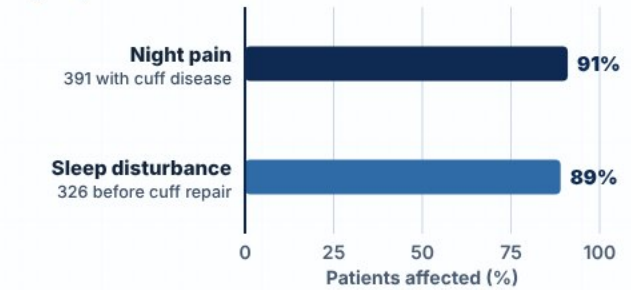


B · On the back
Arm on a pillow



C · Other side
Arm on a pillow

Night pain is common in cuff disease



Khazzam et al. (2018); Dolan et al. (2022). Night pain usually improves as the shoulder improves.

Decision pathway

1. **POSITION**
   Try lying on the back or the pain-free side with the painful arm supported on a pillow.
2. **TREAT**
   Exercise is core; short-term pain relief or a single injection can help night pain.
3. **CHECK**
   Constant, unremitting night pain with general symptoms needs medical review.

SEEK ASSESSMENT IF

Night pain with weight loss, fever, a history of cancer, swollen glands, generalised joint pain, or a bony swelling or mass; suspected infection needs immediate referral.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Dolan, M. T., Lowenstein, N. A., Collins, J. E., & Matzkin, E. G. (2022). Majority of patients find sleep patterns return to normal 6 months following rotator cuff repair. *Journal of Shoulder and Elbow Surgery, 31*, 1687–1695. https://doi.org/10.1016/j.jse.2022.01.122

Holdaway, L. A., Hegmann, K. T., Thiese, M. S., & Kapellusch, J. (2018). Is sleep position associated with glenohumeral shoulder pain and rotator cuff tendinopathy: A cross-sectional study. *BMC Musculoskeletal Disorders, 19*, Article 408. https://doi.org/10.1186/s12891-018-2319-9

Khazzam, M. S., Mulligan, E. P., Brunette-Christiansen, M., & Shirley, Z. (2018). Sleep quality in patients with rotator cuff disease. *Journal of the American Academy of Orthopaedic Surgeons, 26*(6), 215–222. https://doi.org/10.5435/JAAOS-D-16-00547

Mitchell, C., Adebajo, A., Hay, E., & Carr, A. (2005). Shoulder pain: Diagnosis and management in primary care. *BMJ, 331*(7525), 1124–1128. https://doi.org/10.1136/bmj.331.7525.1124

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Werner, C. M., et al. (2010). Subacromial pressures vary with simulated sleep positions. *Journal of Shoulder and Elbow Surgery, 19*, 989–993.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

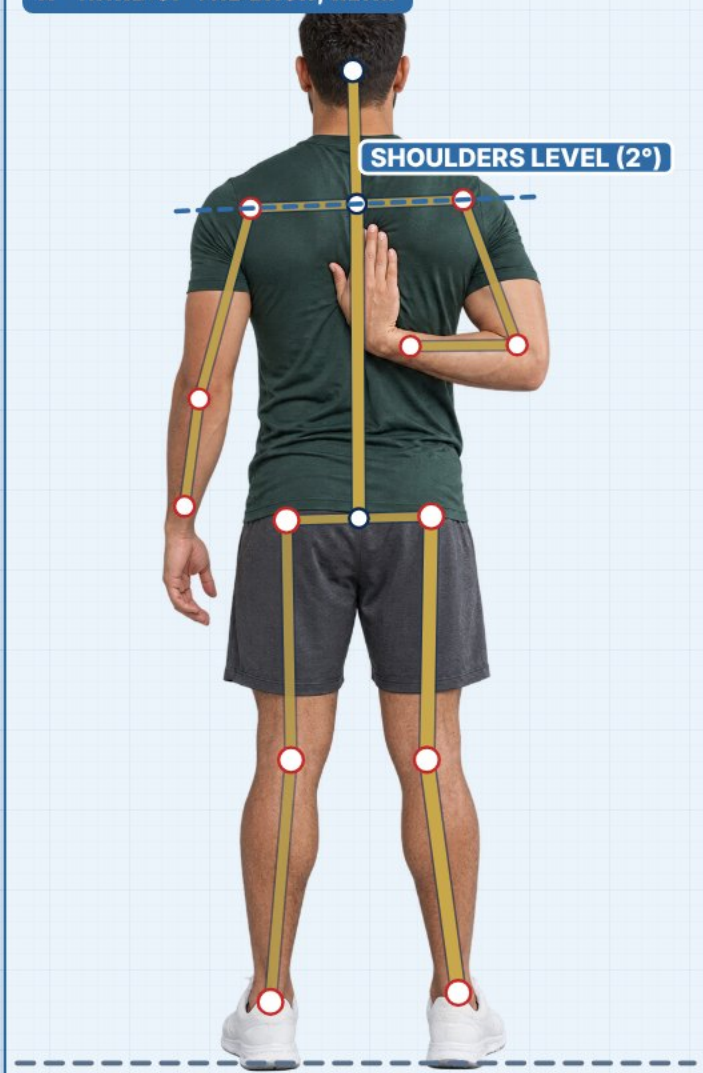
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING BEHIND YOUR BACK: WHAT LIMITED INTERNAL ROTATION MEANS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

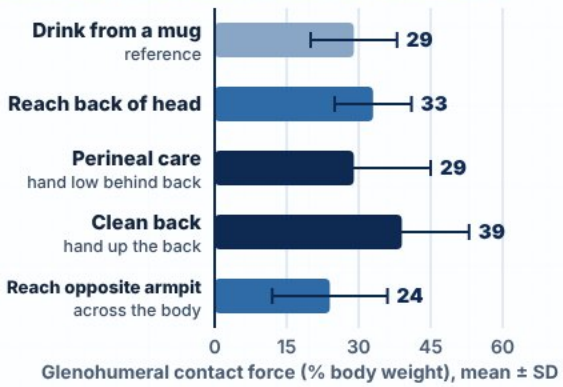
A · HAND UP THE BACK, REAR



Hand up the back: a rotation test

- Sliding the hand up the spine combines internal rotation and extension; the shoulders stay almost level (**2°**), so the reach comes from the shoulder, not a trunk lean.
- Behind-back tasks load the joint only modestly, about 30–40% of body weight, so discomfort here is not simply about how much force passes through it.

Behind-back reaches: modest joint force



25 adults; musculoskeletal model estimates, not implant measurements. Klemt et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the rear view; no arm angle is quoted because the hand is hidden behind the back. Educational, not diagnostic.

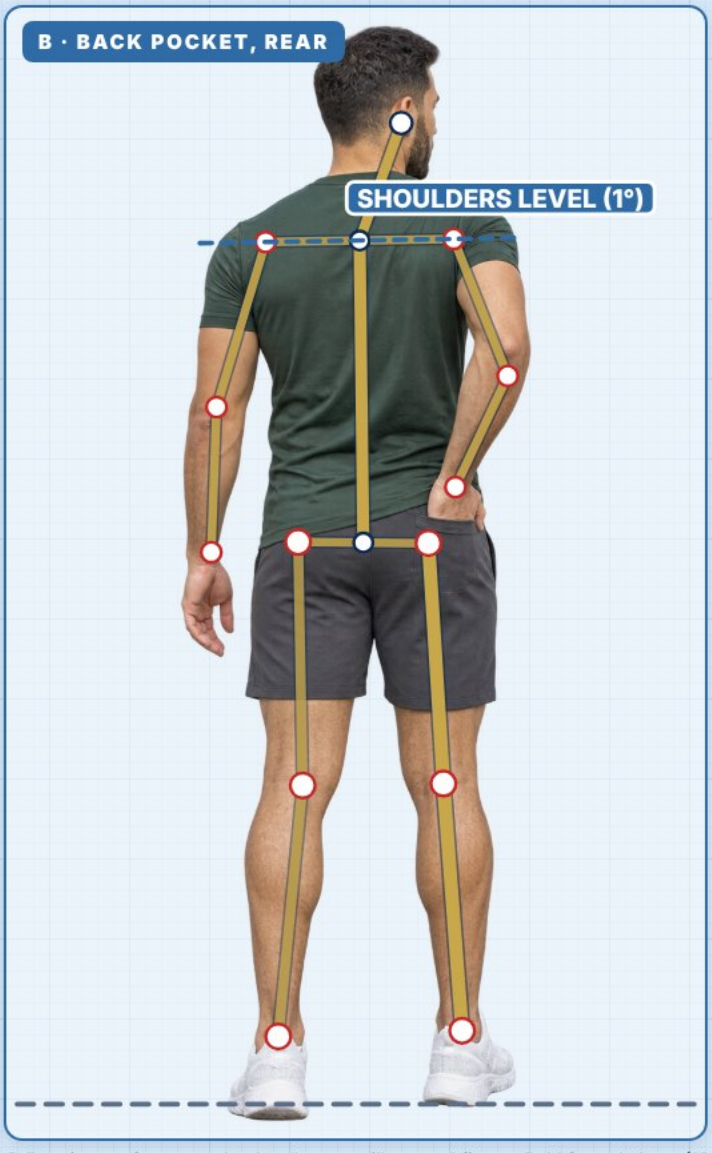
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING BEHIND YOUR BACK: WHAT LIMITED INTERNAL ROTATION MEANS

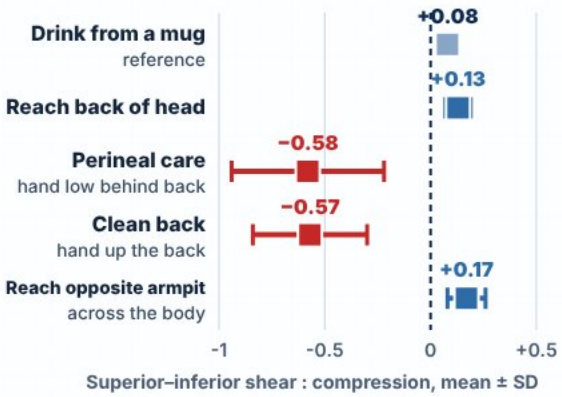
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Back pocket: low reach, high shear

- Reaching into the back pocket, shoulders level (**1°**): a low behind-back reach, close to the "perineal care" task measured in the laboratory.
- In these reaches the joint load is directed much more as shear relative to compression, a demanding position that may help explain why they often feel uncomfortable.

Behind the back, shear dominates



Same 25 adults; negative values = inferiorly directed shear. An association, not proof of a pain mechanism. Klemt et al. (2018).

Key point: if passive rotation is also lost, think capsule (for example frozen shoulder); if passive range is full, think pain or cuff strength.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

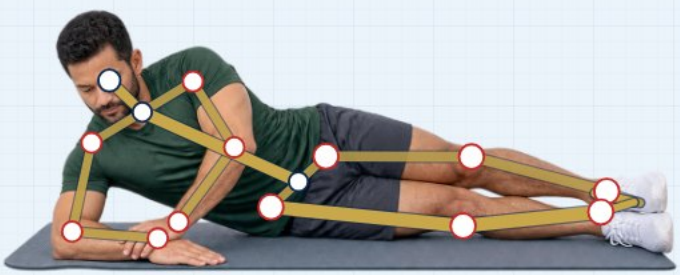
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING BEHIND YOUR BACK: WHAT LIMITED INTERNAL ROTATION MEANS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

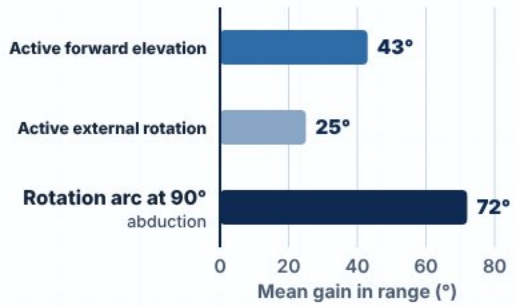
C · SLEEPER STRETCH, FRONT



Side-lying internal rotation stretch

- Lying on the right side, upper arm forward at about shoulder height, the left hand eases the right forearm towards the floor to stretch into internal rotation.
- In frozen shoulder, a four-direction home stretching programme recovered a mean of eight vertebral levels of hand-behind-back reach.

What stretching recovered



75 patients (77 shoulders), phase II frozen shoulder, mean follow-up 22 months. Griggs et al. (2000).

Myth: "Pushing hard through the stretch frees it faster." The guideline matches stretching intensity to the shoulder's irritability.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in lying positions, so no angles are quoted for this frame. Educational, not diagnostic.

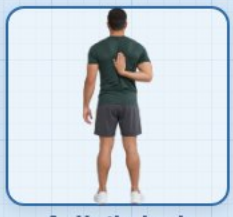
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING BEHIND YOUR BACK: WHAT LIMITED INTERNAL ROTATION MEANS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Up the back
Shoulders 2° tilt

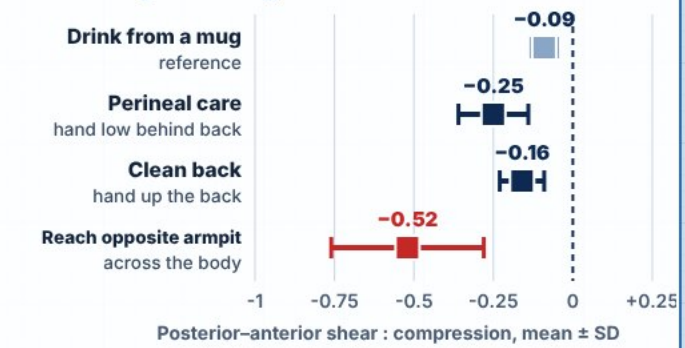


B · Back pocket
Low reach, high shear



C · Sleeper stretch
Into internal rotation

Cross-body reaching adds front–back shear



25 adults, musculoskeletal model; relevant to cross-body stretches and reaches. Klemt et al. (2018).

Decision pathway

1. **MEASURE**
   Record active and passive rotation with a goniometer, inclinometer or validated app, and retest.
2. **INTERPRET**
   Passive loss suggests the capsule; full passive range suggests pain or cuff strength.
3. **STRETCH**
   Stretch the restricted directions at an intensity set by irritability; exercise is core for cuff pain.

NOT RECOMMENDED

Forcing painful end-range stretches.

SEEK ASSESSMENT IF

Loss of rotation after a fall or a "dead arm" episode, infection, a mass, several inflamed joints, or weight loss, fever or a history of cancer.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Griggs, S. M., Ahn, A., & Green, A. (2000). Idiopathic adhesive capsulitis: A prospective functional outcome study of nonoperative treatment. *Journal of Bone and Joint Surgery, American Volume, 82*(10), 1398–1407.

Kelley, M. J., Shaffer, M. A., Kuhn, J. E., Michener, L. A., Seitz, A. L., Uhl, T. L., Godges, J. J., & McClure, P. W. (2013). Shoulder pain and mobility deficits: Adhesive capsulitis. Clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy, 43*(5), A1–A31. https://doi.org/10.2519/jospt.2013.0302

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Mitchell, C., Adebajo, A., Hay, E., & Carr, A. (2005). Shoulder pain: Diagnosis and management in primary care. *BMJ, 331*(7525), 1124–1128. https://doi.org/10.1136/bmj.331.7525.1124

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

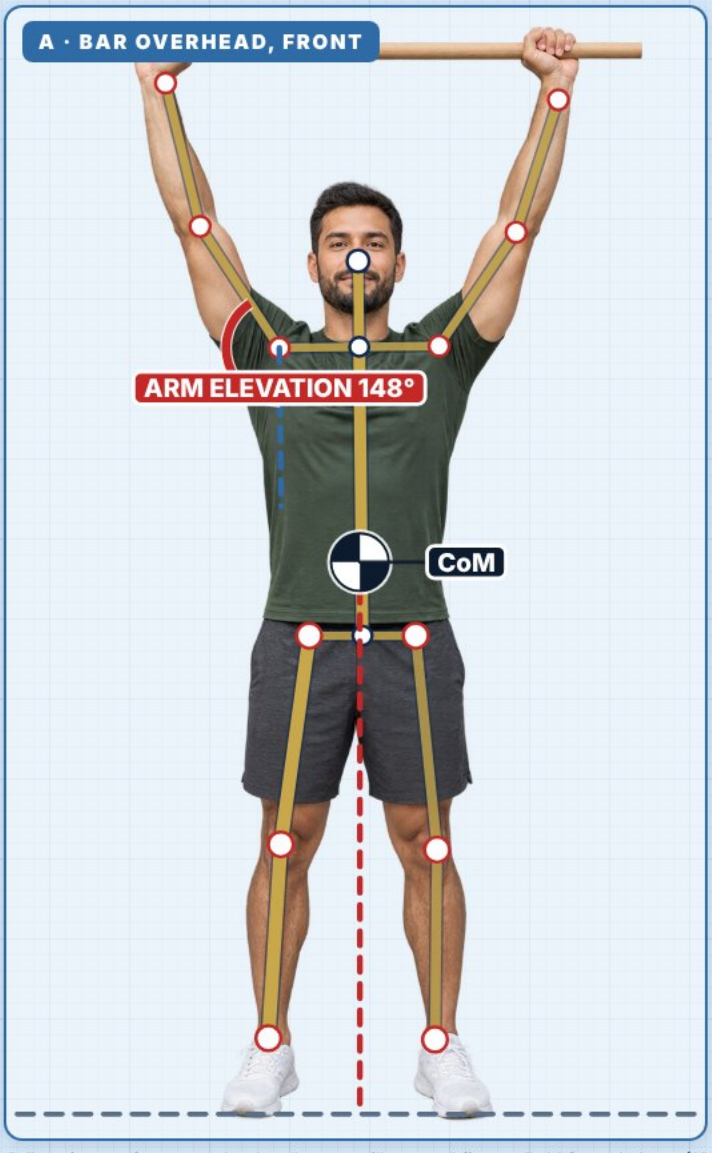
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING OVERHEAD: HOW THE SHOULDER BLADE SHARES THE LOAD

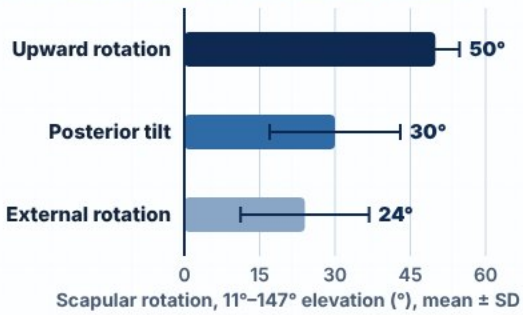
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Overhead is a shared job

- Bar held overhead, arm elevated ≈**148°**. Bone-pin tracking shows roughly one degree in every three of elevation comes from the shoulder blade (1.7 : 1 ratio).
- The shoulder blade does more than rotate upward: it also tilts backward and turns outward, movements thought to help keep the space under the acromion clear.

The shoulder blade moves in three axes



8 healthy volunteers, sensors on bone pins, scapular-plane elevation. McClure et al. (2001).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation: upper arm relative to the trunk line. Educational, not diagnostic.

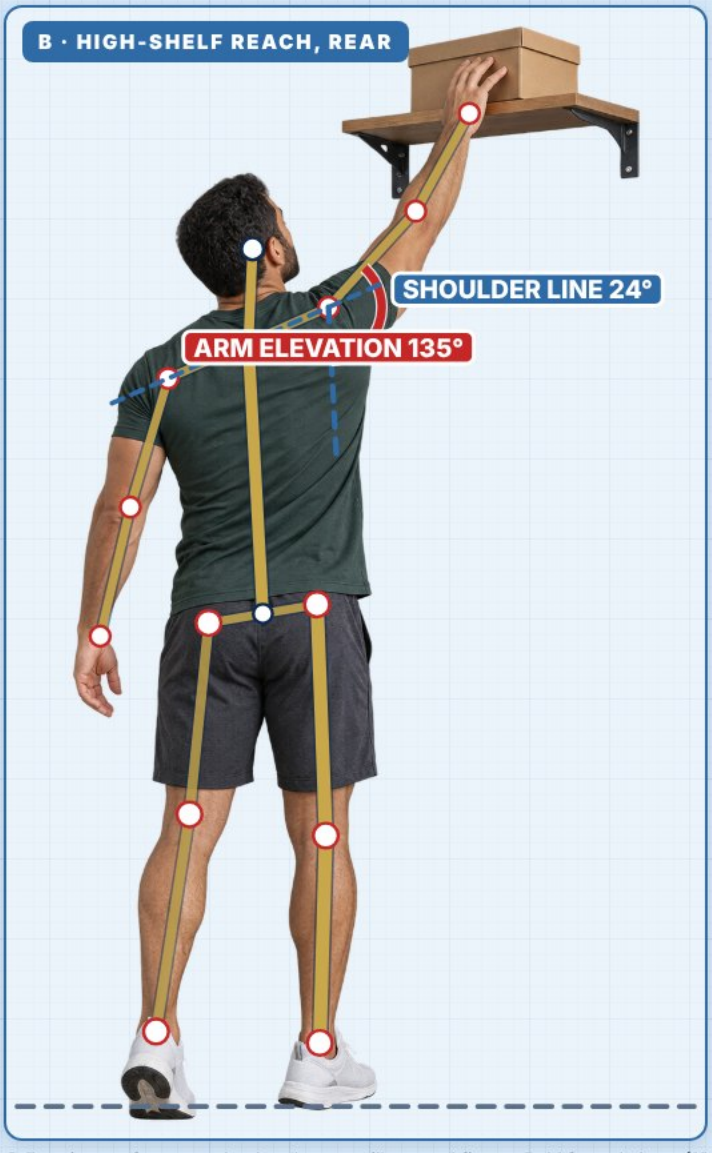
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING OVERHEAD: HOW THE SHOULDER BLADE SHARES THE LOAD

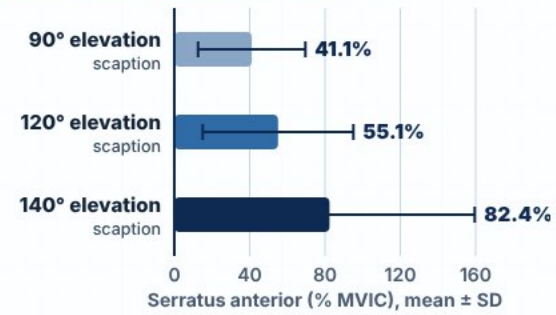
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Higher reach, more serratus work

- Reaching to the shelf, arm at ≈**135°**: the line between the shoulders tilts ≈**24°** as the reaching side rises, a visible sign of the shoulder blade and collarbone elevating.
- Serratus anterior, which rotates the blade upward and tilts it back, worked harder the higher the arm went; the wide spread means individual responses vary.

Serratus activity rises with height



20 healthy adults, surface EMG; activity rose with elevation angle (P = .001). Hardwick et al. (2006).

Key point: a tilted shoulder line in a reach is normal motion, not a fault to correct.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the rear view. Educational, not diagnostic.

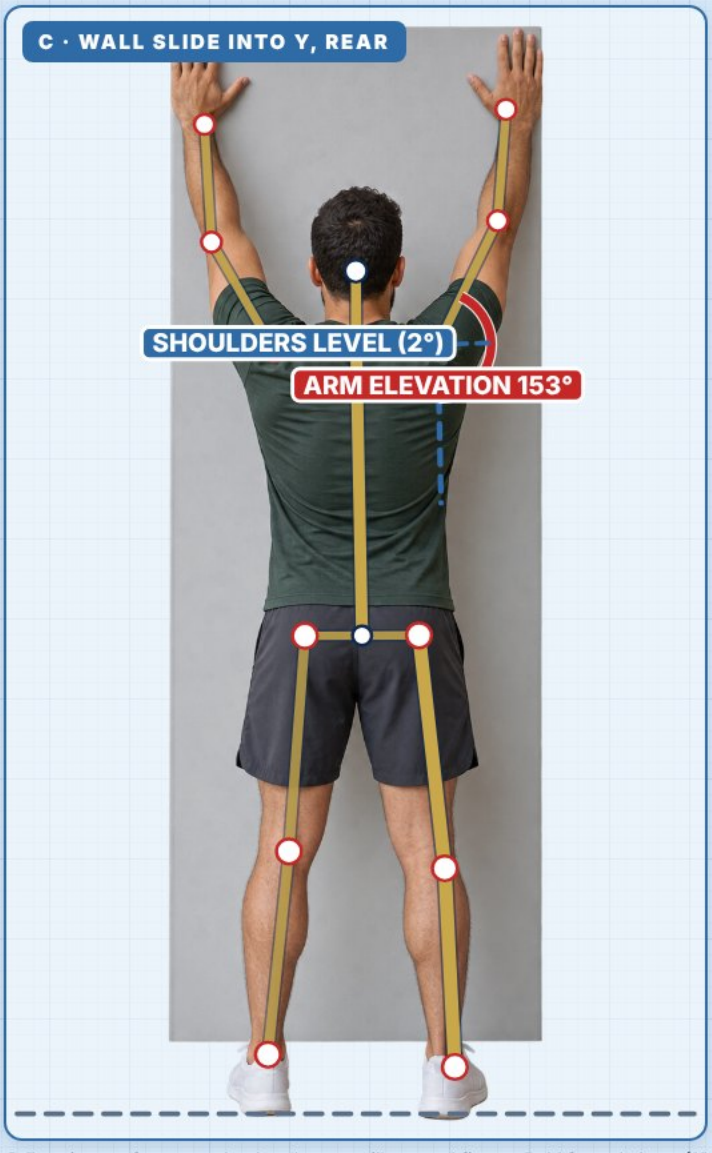
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING OVERHEAD: HOW THE SHOULDER BLADE SHARES THE LOAD

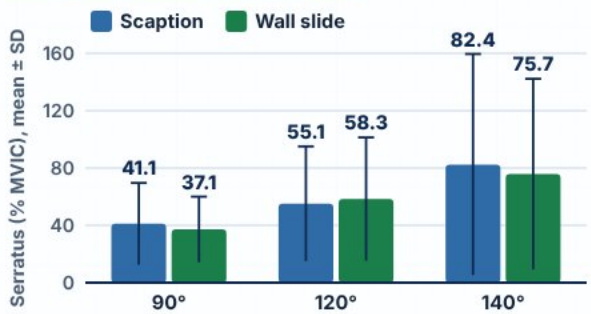
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Wall slide: supported overhead work

- Facing the wall, hands sliding up into a Y to ≈**153°**, shoulders level (**2°**): the wall supports the arms while the blade works in the range where overhead pain is usually felt.
- Serratus activity in the wall slide matched raising the arm in the scapular plane at every angle tested, so it is a gentler route into the same range.

Wall slide matches scaption



Same 20 adults; no difference between wall slide and scaption (P = .36). Hardwick et al. (2006).

Myth: "The shoulder blade must be fixed before you load." Scapular work helps short term, alongside other exercise.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and shoulder line from pose landmarks in the rear view. Educational, not diagnostic.

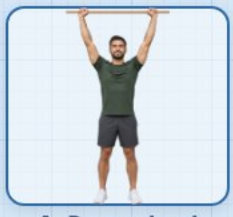
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN REACHING OVERHEAD: HOW THE SHOULDER BLADE SHARES THE LOAD

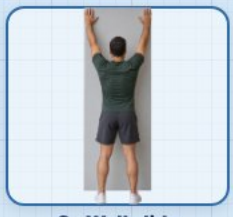
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Bar overhead
Arm ≈148°

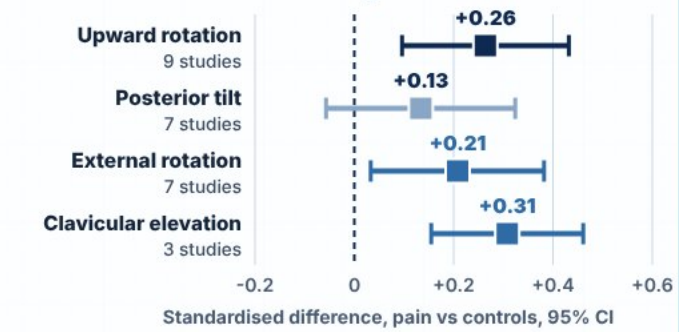


B · Shelf reach
Shoulder line 24°



C · Wall slide
Supported overhead

Painful shoulders: small scapular differences



Meta-analysis of 9 case-control studies, subacromial pain vs controls; all effects small and may be adaptations, not causes. Timmons et al. (2012).

Decision pathway

1. **EDUCATE**
   Explain that overhead reach shares motion between arm and shoulder blade, and that pain is not damage.
2. **LOAD**
   Progress cuff and scapular exercise into overhead range, using supported options such as the wall slide.
3. **REVIEW**
   If no better by 6–8 weeks, discuss options; refer if no improvement by 12 weeks.

NOT RECOMMENDED

Arthroscopic subacromial decompression as first-line treatment; waiting for "perfect" scapular motion before loading.

SEEK ASSESSMENT IF

Suspected fracture or dislocation after injury, fever or a hot swollen shoulder, a lump, several inflamed joints, or shoulder pain in a child.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hardwick, D. H., Beebe, J. A., McDonnell, M. K., & Lang, C. E. (2006). A comparison of serratus anterior muscle activation during a wall slide exercise and other traditional exercises. *Journal of Orthopaedic & Sports Physical Therapy, 36*(12), 903–910. https://doi.org/10.2519/jospt.2006.2306

McClure, P. W., Michener, L. A., Sennett, B. J., & Karduna, A. R. (2001). Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. *Journal of Shoulder and Elbow Surgery, 10*(3), 269–277. https://doi.org/10.1067/mse.2001.112954

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Saito, H., Harrold, M. E., Cavalheri, V., & McKenna, L. (2018). Scapular focused interventions to improve shoulder pain and function in adults with subacromial pain: A systematic review and meta-analysis. *Physiotherapy Theory and Practice, 34*(9), 653–670. https://doi.org/10.1080/09593985.2018.1423656

Timmons, M. K., Thigpen, C. A., Seitz, A. L., Karduna, A. R., Arnold, B. L., & Michener, L. A. (2012). Scapular kinematics and subacromial-impingement syndrome: A meta-analysis. *Journal of Sport Rehabilitation, 21*(4), 354–370.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

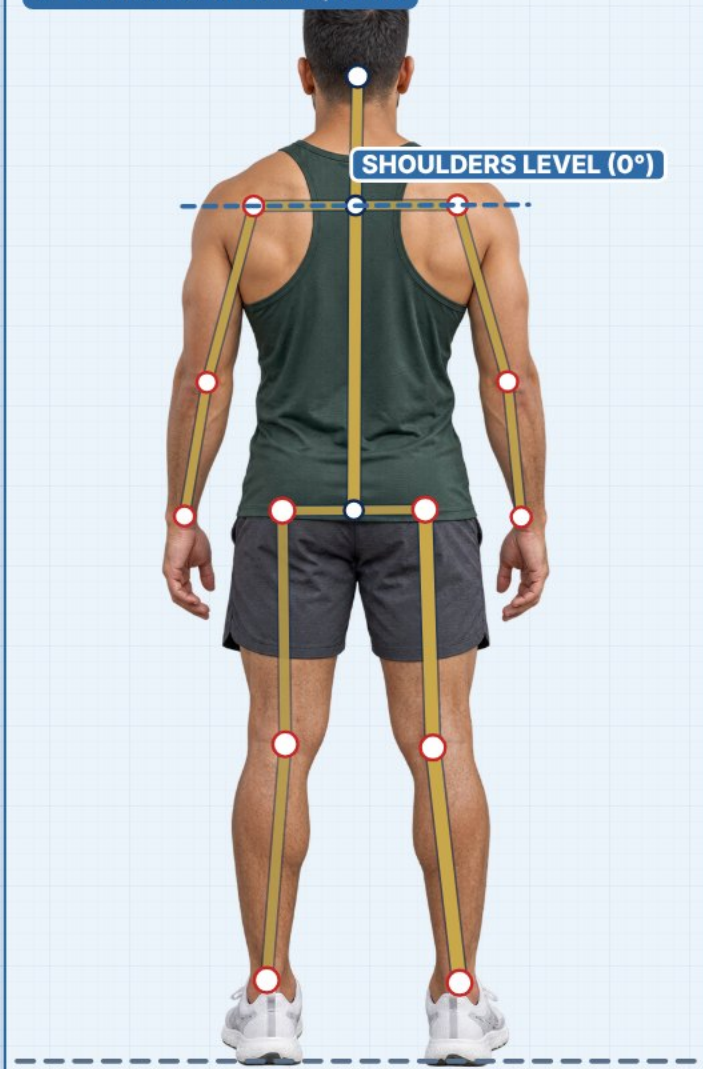
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BLADE MOVEMENT (SCAPULAR DYSKINESIS): WHEN IT MATTERS AND WHEN IT DOESN'T

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

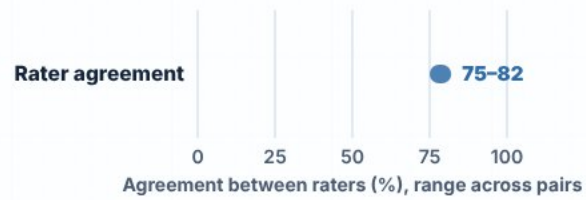
A · STANDING RELAXED, REAR



A still posture says little

- Standing relaxed, shoulders level (**0°**). Dyskinesis means a visible change in shoulder-blade position or motion, so it is judged during movement, not at rest.
- The consensus view treats it as a possible impairment within the whole shoulder assessment, not as a diagnosis in itself.

Raters agree only moderately



142 overhead athletes filmed from behind, 3 rater pairs; weighted kappa 0.48–0.61. McClure et al. (2009).

Myth: "An uneven shoulder blade is the cause of your pain." Seeing it does not show it is the pain source.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

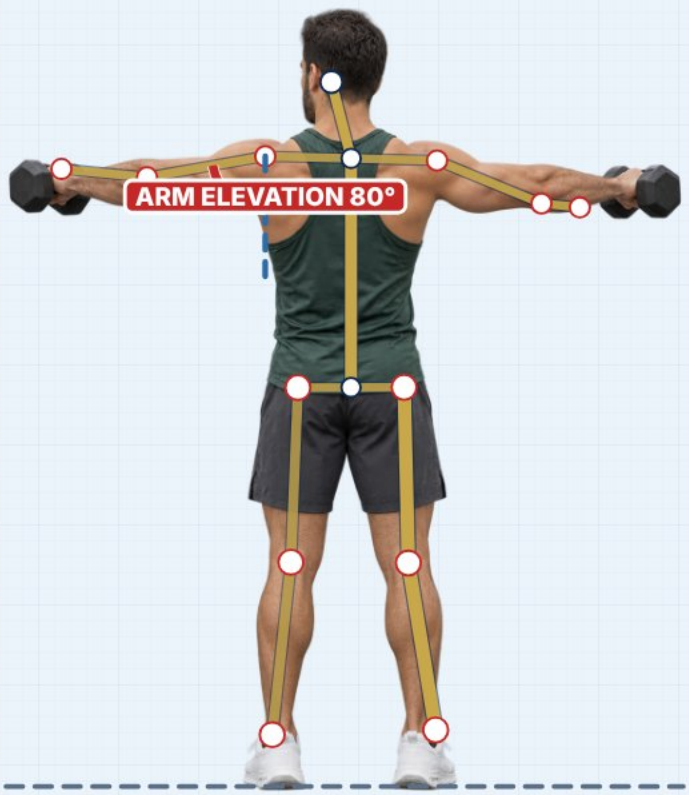
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BLADE MOVEMENT (SCAPULAR DYSKINESIS): WHEN IT MATTERS AND WHEN IT DOESN'T

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

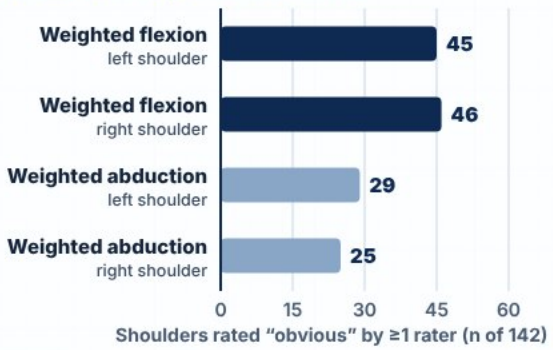
B · DUMBBELLS OUT WIDE, REAR



Light weights make it easier to see

- Dumbbells raised out to the sides to ≈**80°**, just below shoulder height. The clinical test uses a light load (1.4 or 2.3 kg) over five repetitions.
- Raising the arms forward with weights revealed obvious dyskinesis more often than raising them out to the side.

Forward raising shows it more



142 NCAA overhead athletes; 5 repetitions per movement, filmed from behind. McClure et al. (2009).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation from pose landmarks in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

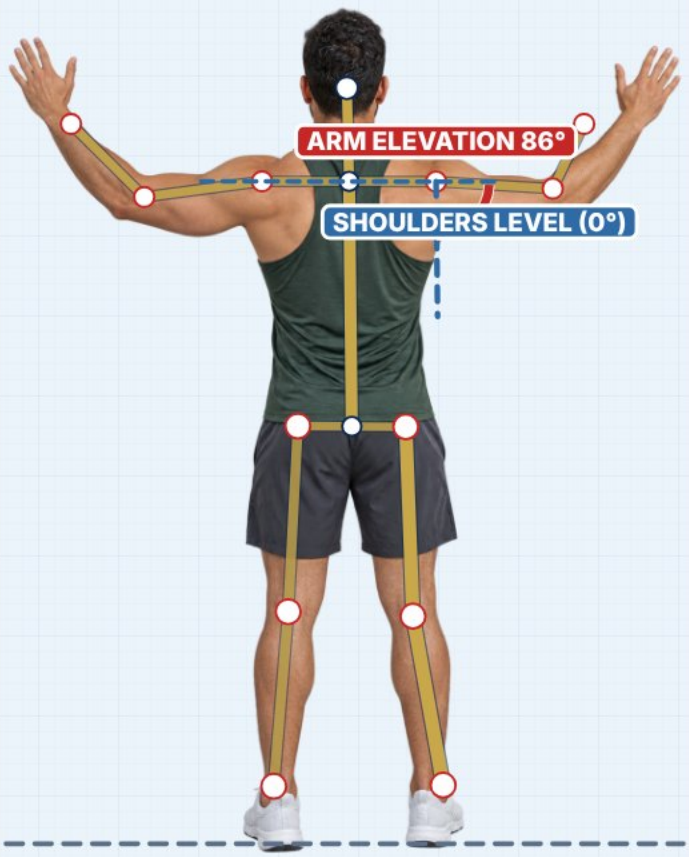
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BLADE MOVEMENT (SCAPULAR DYSKINESIS): WHEN IT MATTERS AND WHEN IT DOESN'T

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

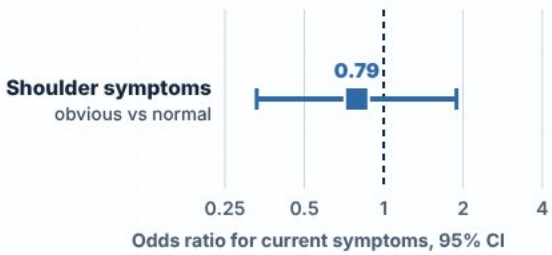
C · LOWERING THE ARMS, REAR



Watch the lowering phase

- Lowering from overhead, arms now ≈**86°** from the trunk: the eccentric return is where uneven or early shoulder-blade motion is often easiest to spot.
- In 3-D testing, shoulders rated "obvious" had less upward rotation, yet these athletes were no more likely to report symptoms.

Seen, but not linked to symptoms



142 athletes rated visually, 66 with 3-D kinematics; CI crosses 1.0 (no association). Tate et al. (2009).

Key point: what clinicians see reflects real 3-D differences, but that alone does not make it the pain source.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and shoulder line from pose landmarks in the rear view. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

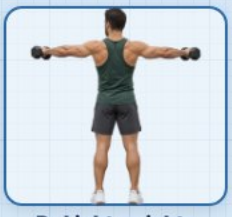
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BLADE MOVEMENT (SCAPULAR DYSKINESIS): WHEN IT MATTERS AND WHEN IT DOESN'T

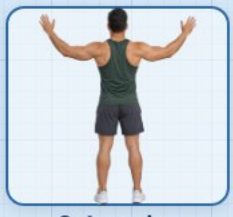
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · At rest
Shoulders 0°

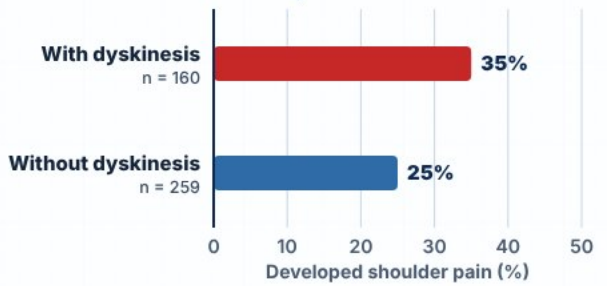


B · Light weights
Arms ≈80°



C · Lowering
Watch the return

A modest risk marker in pain-free athletes



419 asymptomatic athletes, 5 prospective studies, 9–24 months; RR 1.43 (95% CI 1.05–1.93). Hickey et al. (2018).

Decision pathway

1. **OBSERVE**
   Judge shoulder-blade motion with light weights over repeated raising and lowering, not at rest.
2. **INTERPRET**
   Weigh it within the whole shoulder assessment; on its own it is not a diagnosis.
3. **TRAIN**
   Add scapular work inside a progressive cuff and shoulder programme; do not treat a pain-free asymmetry.

NOT RECOMMENDED

Labelling a visible asymmetry in a pain-free shoulder as a disorder that needs treatment.

SEEK ASSESSMENT IF

Marked or sudden winging, especially after injury, heavy lifting or a viral illness; clear weakness or loss of overhead reach; suspected fracture, infection or a lump.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hickey, D., Solvig, V., Cavalheri, V., Harrold, M., & Mckenna, L. (2018). Scapular dyskinesis increases the risk of future shoulder pain by 43% in asymptomatic athletes: A systematic review and meta-analysis. *British Journal of Sports Medicine, 52*(2), 102–110. https://doi.org/10.1136/bjsports-2017-097559

Kibler, W. B., Ludewig, P. M., McClure, P. W., Michener, L. A., Bak, K., & Sciascia, A. D. (2013). Clinical implications of scapular dyskinesis in shoulder injury: The 2013 consensus statement from the 'scapular summit'. *British Journal of Sports Medicine, 47*(14), 877–885. https://doi.org/10.1136/bjsports-2013-092425

McClure, P., Tate, A. R., Kareha, S., Irwin, D., & Zlupko, E. (2009). A clinical method for identifying scapular dyskinesis, part 1: Reliability. *Journal of Athletic Training, 44*(2), 160–164. https://doi.org/10.4085/1062-6050-44.2.160

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Saito, H., Harrold, M. E., Cavalheri, V., & McKenna, L. (2018). Scapular focused interventions to improve shoulder pain and function in adults with subacromial pain: A systematic review and meta-analysis. *Physiotherapy Theory and Practice, 34*(9), 653–670. https://doi.org/10.1080/09593985.2018.1423656

Tate, A. R., McClure, P., Kareha, S., Irwin, D., & Barbe, M. F. (2009). A clinical method for identifying scapular dyskinesis, part 2: Validity. *Journal of Athletic Training, 44*(2), 165–173. https://doi.org/10.4085/1062-6050-44.2.165

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

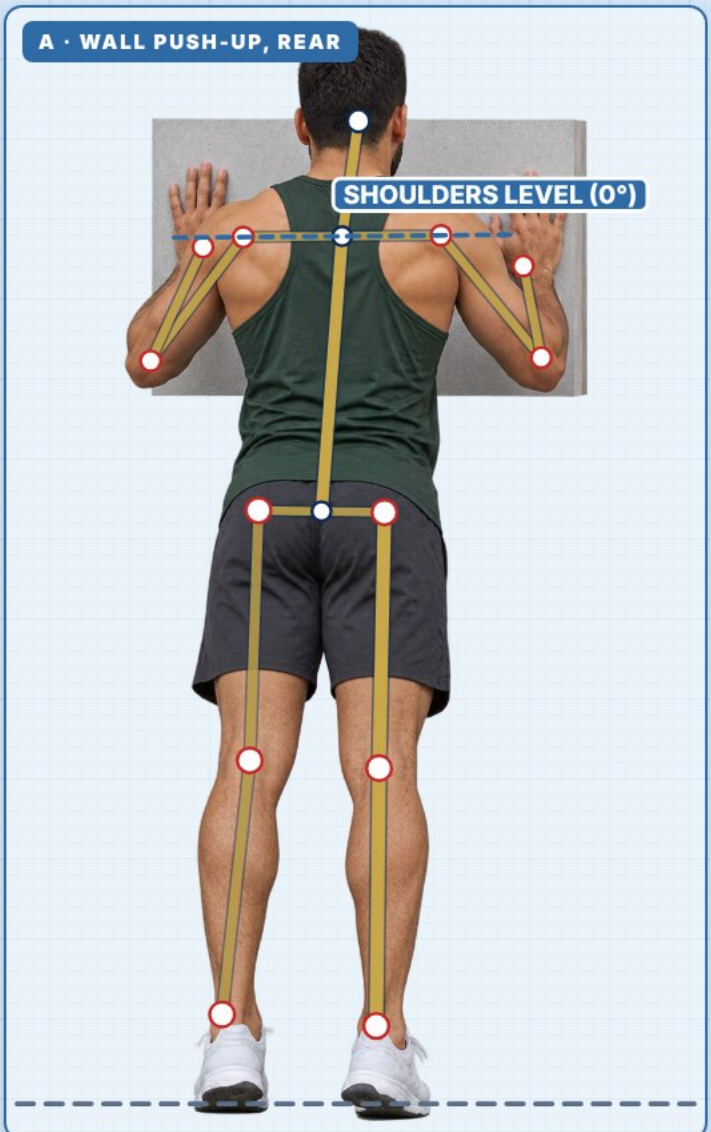
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WINGING SHOULDER BLADE: MUSCLE WEAKNESS OR NERVE PROBLEM?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

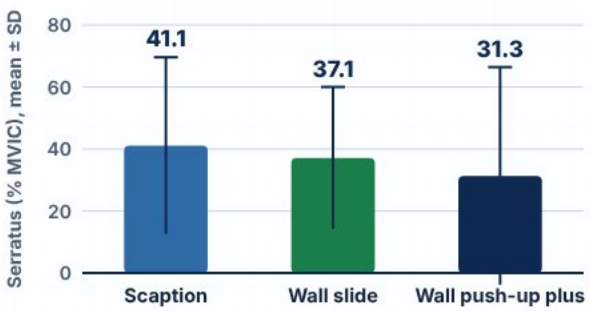
A · WALL PUSH-UP, REAR



Wall push-up: an easy entry point

- Hands on the wall at shoulder height, shoulders level (**0°**): leaning in loads the serratus anterior, which holds the inner border of the shoulder blade against the ribs.
- Mild, symmetrical prominence that settles with cueing or practice usually reflects motor control or deconditioning rather than nerve damage.

Moderate serratus work at 90°



20 healthy adults, surface EMG at 90° elevation; no difference between exercises (P = .40). Hardwick et al. (2006).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the rear view. Educational, not diagnostic.

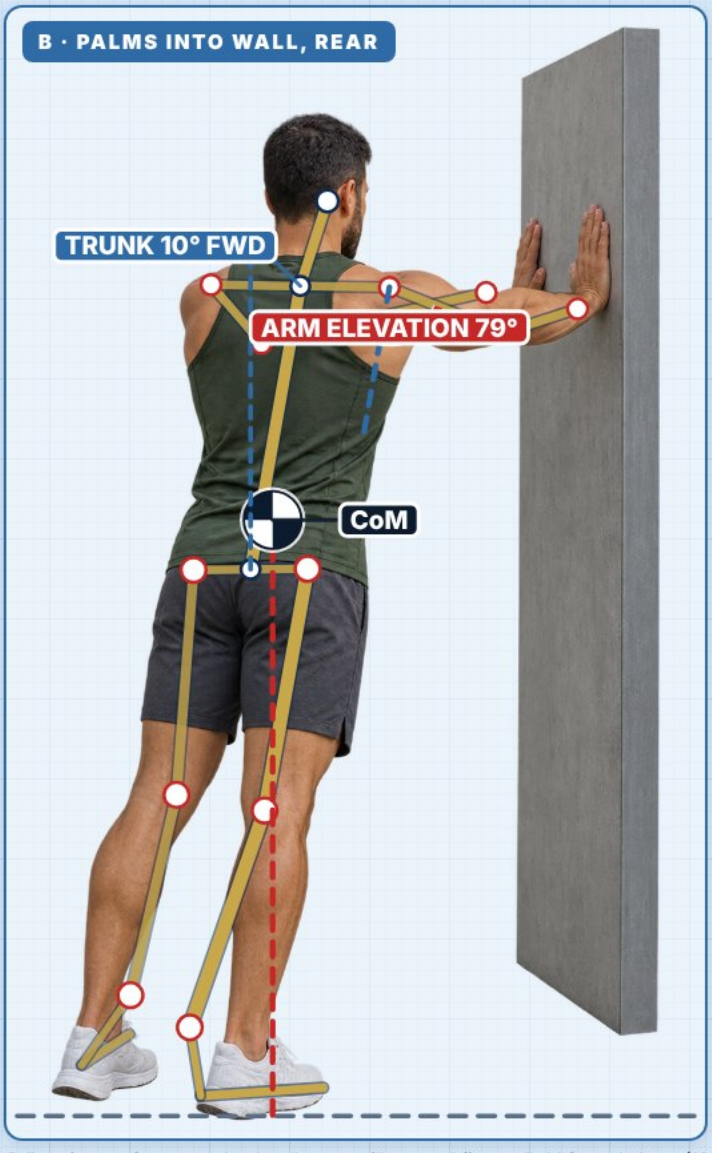
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WINGING SHOULDER BLADE: MUSCLE WEAKNESS OR NERVE PROBLEM?

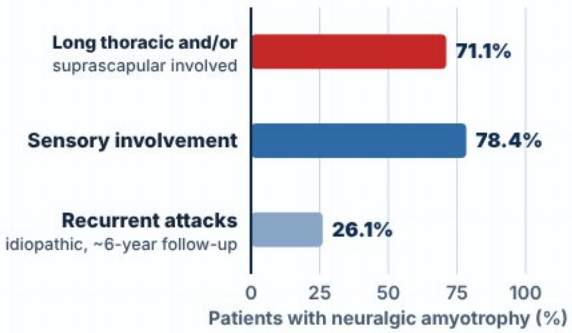
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A low-load test position

- Arms forward at ≈**79°**, leaning ≈**10°** into the wall: a light push. A shoulder blade that lifts away from the ribs even here is a useful clinical sign.
- Severe shoulder pain lasting weeks, then weakness and winging as the pain eases, points to a nerve problem such as neuralgic amyotrophy.

Neuralgic amyotrophy: nerve involvement



246 patients (199 idiopathic, 47 hereditary); initial pain lasted about 4 weeks on average. van Alfen & van Engelen (2006).

Myth: "Winging always means a weak serratus that more push-ups will fix." A nerve palsy is a distinct cause.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and trunk lean from pose landmarks; the camera is behind and to one side, so angles are approximate. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

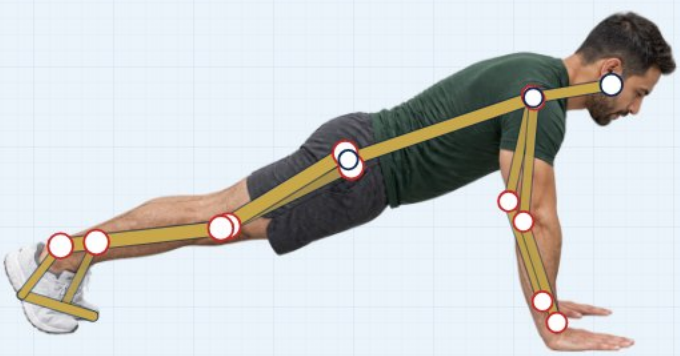
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WINGING SHOULDER BLADE: MUSCLE WEAKNESS OR NERVE PROBLEM?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

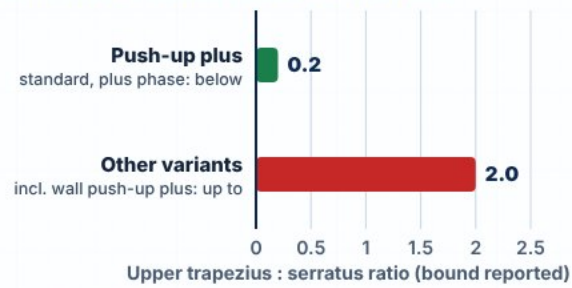
C · PUSH-UP PLUS, SIDE



Push-up plus: the harder progression

- Arms straight on the floor, pushing the upper back towards the ceiling: the "plus" draws the shoulder blades forward around the ribs.
- The standard push-up plus produced the highest serratus activity of the variants tested (123% MVIC) with little upper trapezius activity.

Selective serratus work in the plus



30 adults, healthy or with mild shoulder dysfunction, surface EMG; lower ratio = more selective serratus work. Ludewig et al. (2004).

Key point: winging that persists despite good effort suggests weakness that needs assessment.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in push-up positions, so no angles are quoted for this frame. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WINGING SHOULDER BLADE: MUSCLE WEAKNESS OR NERVE PROBLEM?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Wall push-up
Entry level

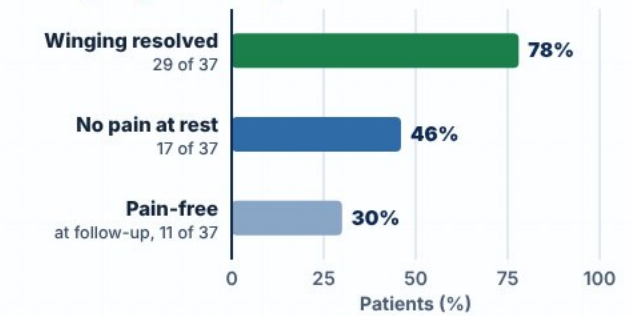


B · Palms into wall
Low-load test



C · Push-up plus
Progression

Nerve palsy: recovery is common but slow



37 patients with isolated serratus palsy, observation only, median follow-up 18 years; winging lasted 16 months on average (range 2–30). Pikkarainen et al. (2013).

Decision pathway

1. **HISTORY**
   Ask about pain onset, injury, surgery, heavy carrying and numbness; these separate nerve from muscle.
2. **TRAIN**
   For motor-control winging, progress from wall push-up plus to floor push-up plus and overhead work.
3. **REFER**
   Suspected nerve palsy needs medical assessment; expect months of recovery and monitor progress.

NOT RECOMMENDED

Loading a muscle with confirmed acute denervation hard into fatigue without specialist guidance.

SEEK ASSESSMENT IF

Sudden severe shoulder or neck pain followed by weakness or winging; winging after injury or neck, chest-wall or armpit surgery; numbness or weakness elsewhere in the arm.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hardwick, D. H., Beebe, J. A., McDonnell, M. K., & Lang, C. E. (2006). A comparison of serratus anterior muscle activation during a wall slide exercise and other traditional exercises. *Journal of Orthopaedic & Sports Physical Therapy, 36*(12), 903–910. https://doi.org/10.2519/jospt.2006.2306

Ludewig, P. M., Hoff, M. S., Osowski, E. E., Meschke, S. A., & Rundquist, P. J. (2004). Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises. *American Journal of Sports Medicine, 32*(2), 484–493. https://doi.org/10.1177/0363546503258911

Pikkarainen, V., Kettunen, J., & Vastamäki, M. (2013). The natural course of serratus palsy at 2 to 31 years. *Clinical Orthopaedics and Related Research, 471*(5). https://doi.org/10.1007/s11999-012-2723-7

van Alfen, N., & van Engelen, B. G. M. (2006). The clinical spectrum of neuralgic amyotrophy in 246 cases. *Brain, 129*, 438–450.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

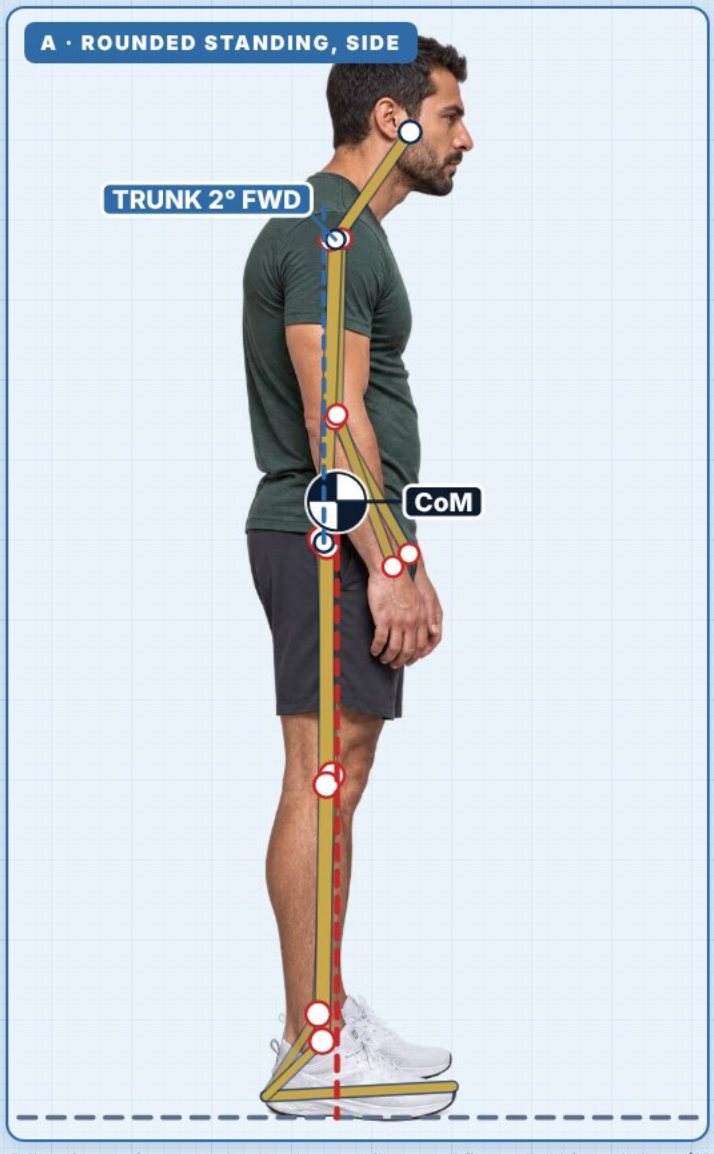
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROUNDED SHOULDERS AND POSTURE: DOES CORRECTING IT REDUCE PAIN?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

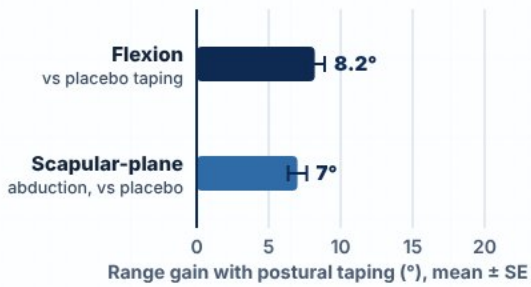


2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk line from hip to shoulder points; it does not measure thoracic curvature. Educational, not diagnostic.

Rounded posture: a description

- Head forward, upper back rounded, shoulders drawn forward. The hip-to-shoulder line is still **≈2°** from vertical: the change sits in the upper back and neck.
- Even in pain-free adults, taping the upper back and shoulder blades into a more upright position increased arm range more than placebo taping.

Posture changes available range



60 asymptomatic adults, single session, thoracic and scapular postural taping vs placebo taping. Lewis et al. (2005).

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROUNDED SHOULDERS AND POSTURE: DOES CORRECTING IT REDUCE PAIN?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

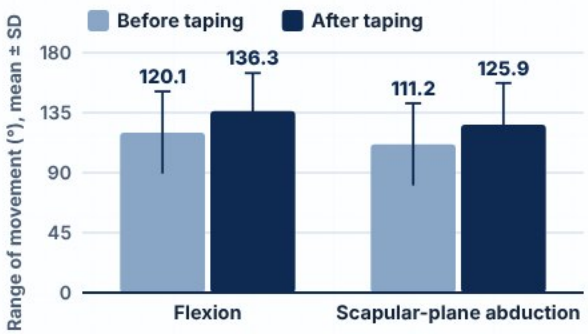
B · UPRIGHT STANDING, SIDE



Upright: more room to lift the arm

- Relaxed tall posture, trunk line within ≈**1°** of vertical. In people with impingement-type pain, taping into this position added about 15–16° of range.
- Pain began later in the movement, but pain intensity did not change significantly, so the effect is on range, not proof of a cause.

Painful shoulders: range before and after



60 people with subacromial impingement syndrome, single session; range rose ($P < .001$), pain did not change significantly. Lewis et al. (2005).

Key point: posture is a dial for range, not a proven cause of pain.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk line from hip to shoulder points; it does not measure thoracic curvature. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

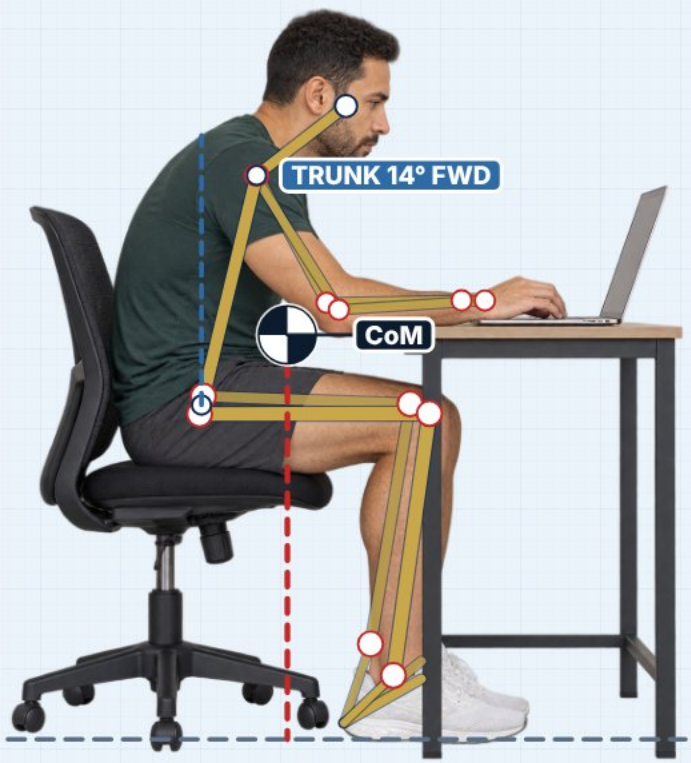
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROUNDED SHOULDERS AND POSTURE: DOES CORRECTING IT REDUCE PAIN?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

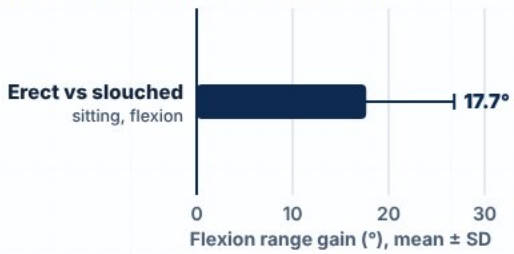
C · SLUMPED AT A DESK, SIDE



Slumped at the desk

- Sitting at the laptop with the trunk ≈**14°** forward and shoulders rounded, forearms resting on the desk: a common working posture, not an injury.
- Sitting tall let painful shoulders lift about 18° higher, yet the pain felt at the top of the movement did not change.

Sitting tall: more range, same pain



28 people with shoulder impingement; pain at maximum flexion no different (P = 0.179). Bullock et al. (2005).

Myth: "Fix your posture and the pain will go." Range improved; pain did not.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk line from hip to shoulder points in the side view. Educational, not diagnostic.

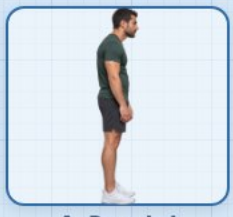
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

ROUNDED SHOULDERS AND POSTURE: DOES CORRECTING IT REDUCE PAIN?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Rounded
Upper back and head

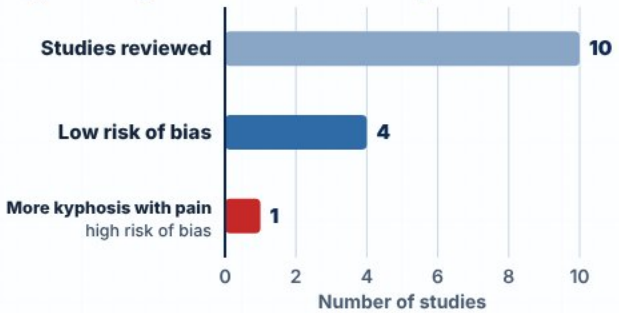


B · Upright
More range



C · Desk slump
Same pain

Is kyphosis greater with shoulder pain?



Systematic review, 10 studies; strong evidence that erect posture increases maximum range ($p < 0.001$), long-term benefit unclear. Barrett et al. (2016).

Decision pathway

1. **REASSURE**
   Explain that posture varies widely in people without pain and is not damaging the shoulder.
2. **USE**
   Try sitting or standing taller, or taping, as a short-term way to make lifting the arm easier.
3. **LOAD**
   Keep progressive exercise as the core; refer if there is no improvement by 12 weeks.

NOT RECOMMENDED

Telling people their posture is causing damage, or making posture correction a condition before loading.

SEEK ASSESSMENT IF

A progressive or fixed upper-back curve, night back pain or pain after minor trauma in older adults, or neck or arm pain with numbness or weakness.

REFERENCES (APA 7)

Barrett, E., O'Keeffe, M., O'Sullivan, K., Lewis, J., & McCreesh, K. (2016). Is thoracic spine posture associated with shoulder pain, range of motion and function? A systematic review. *Manual Therapy, 26*, 38–46. https://doi.org/10.1016/j.math.2016.07.008

Bullock, M. P., Foster, N. E., & Wright, C. C. (2005). Shoulder impingement: The effect of sitting posture on shoulder pain and range of motion. *Manual Therapy, 10*, 28–37. https://doi.org/10.1016/j.math.2004.07.002

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Lewis, J. S., Wright, C., & Green, A. (2005). Subacromial impingement syndrome: The effect of changing posture on shoulder range of movement. *Journal of Orthopaedic & Sports Physical Therapy, 35*(2), 72–87.

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

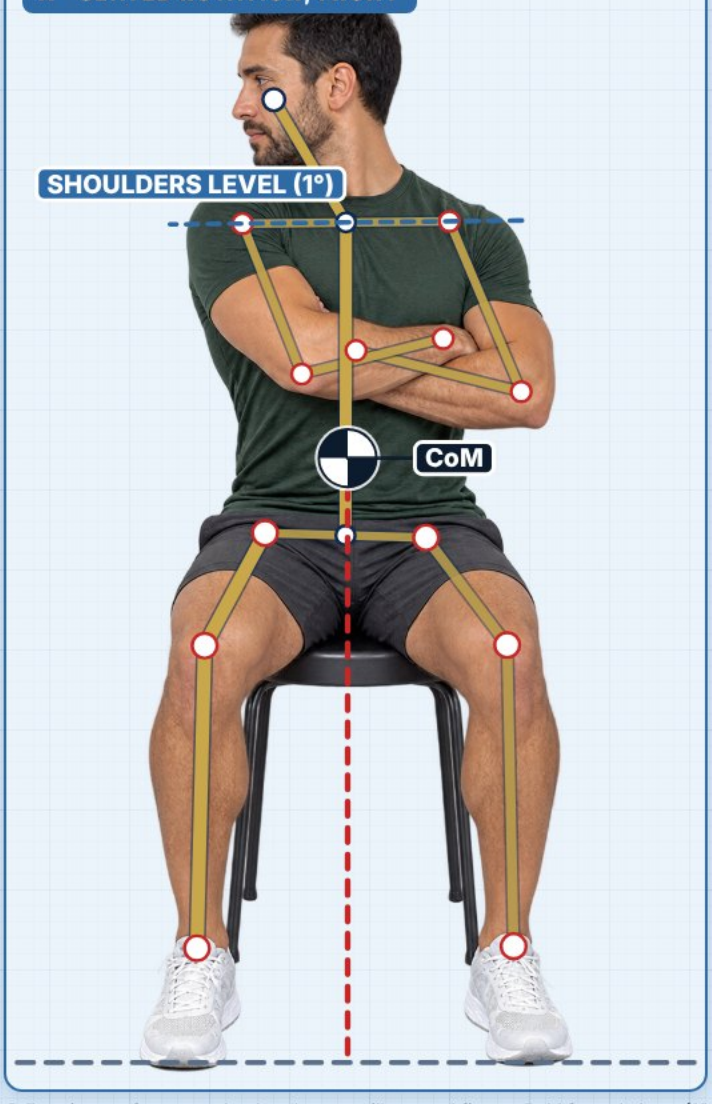
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THORACIC SPINE STIFFNESS: CAN THE UPPER BACK CHANGE SHOULDER LOADING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

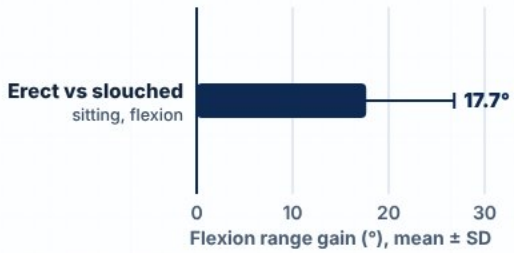
A · SEATED ROTATION, FRONT



Seated rotation: moving the upper back

- Arms crossed on the chest, turning the upper body and head to one side with the shoulders level (**1°**): the stool holds the pelvis, so the turn comes from the spine.
- Thoracic position matters for overhead range: sitting erect rather than slouched let painful shoulders lift about 18° higher.

Upper-back position changes range



28 people with shoulder impingement; pain at maximum flexion did not change (P = 0.179). Bullock et al. (2005).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

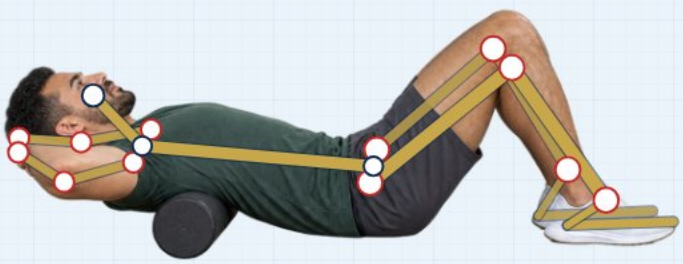
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THORACIC SPINE STIFFNESS: CAN THE UPPER BACK CHANGE SHOULDER LOADING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

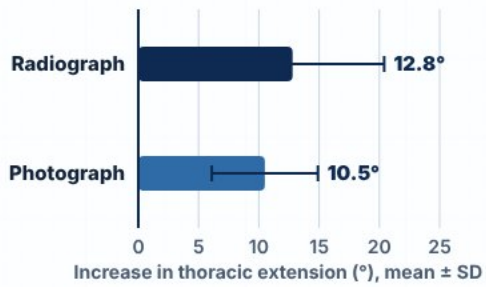
B · FOAM-ROLLER EXTENSION, SIDE



Foam roller: practising extension

- Lying on the back with a foam roller under the upper back, hands behind the head, knees bent and hips down, he extends gently over the roller.
- Getting both arms fully overhead normally borrows about 10–13° of thoracic extension, so the upper back is part of the overhead range budget.

Arms overhead: the upper back extends



21 asymptomatic men, neutral standing to full bilateral arm elevation. Edmondston et al. (2012).

Key point: mobility gains may help reach, but range is not the same as pain relief.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable lying down, so no angles are quoted for this frame. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

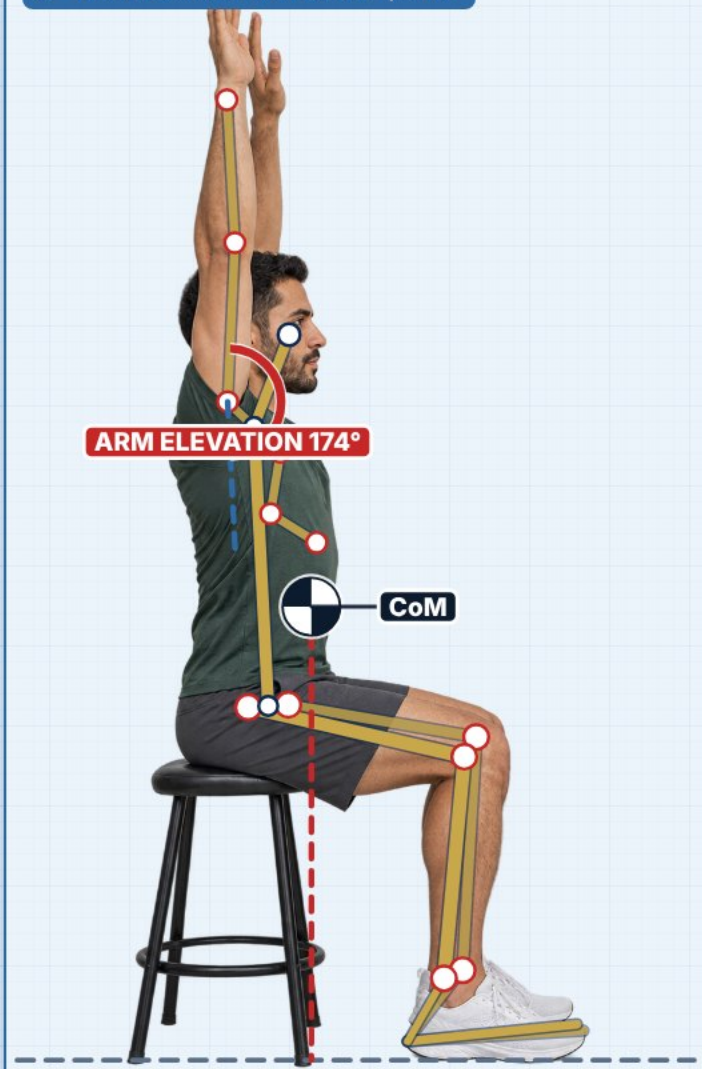
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THORACIC SPINE STIFFNESS: CAN THE UPPER BACK CHANGE SHOULDER LOADING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

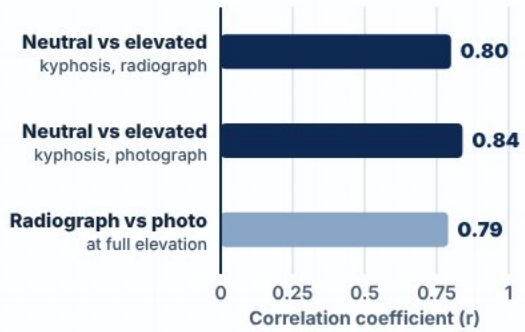
C · SEATED ARMS OVERHEAD, SIDE



Seated overhead reach

- Sitting tall, arms straight overhead at ≈**174°**: the arm's weight sits almost directly over the joint, so reaching full height depends on range more than strength.
- People who start more rounded stay relatively more rounded with the arms overhead, which may limit their final few degrees.

Start rounded, stay rounded



Same 21 men; all correlations P < .001; photographs agreed well with radiographs. Edmondston et al. (2012).

Myth: "Your stiff upper back is jamming your shoulder." Kyphosis is not consistently linked with shoulder pain.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation: upper arm relative to the trunk line. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THORACIC SPINE STIFFNESS: CAN THE UPPER BACK CHANGE SHOULDER LOADING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Rotation
Upper-back mobility

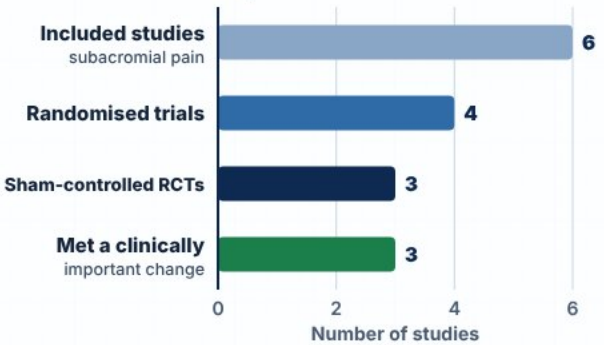


B · Foam roller
Extension practice



C · Arms overhead
Arm ≈174°

Thoracic thrust manipulation: the trials



Systematic review of 6 studies; 2 RCTs found no significant difference between active and sham manipulation for disability. Minkalis et al. (2017).

Decision pathway

1. **ASSESS**
   Check upper-back extension and rotation as part of overhead range, not as the cause of pain.
2. **ADD**
   Use thoracic mobility work or manual therapy as a short-term adjunct for comfort and range.
3. **LOAD**
   Keep progressive shoulder exercise as the core; refer if no improvement by 12 weeks.

NOT RECOMMENDED

Describing a stiff upper back as the cause of shoulder damage, or relying on manipulation alone.

SEEK ASSESSMENT IF

Unexplained weight loss, a history of cancer, fever, significant trauma, spreading numbness or weakness, or constant night-time upper-back pain unrelated to movement.

REFERENCES (APA 7)

Barrett, E., O'Keeffe, M., O'Sullivan, K., Lewis, J., & McCreesh, K. (2016). Is thoracic spine posture associated with shoulder pain, range of motion and function? A systematic review. *Manual Therapy, 26*, 38–46. https://doi.org/10.1016/j.math.2016.07.008

Bullock, M. P., Foster, N. E., & Wright, C. C. (2005). Shoulder impingement: The effect of sitting posture on shoulder pain and range of motion. *Manual Therapy, 10*, 28–37. https://doi.org/10.1016/j.math.2004.07.002

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Edmondston, S. J., Ferguson, A., Ippersiel, P., Ronningen, L., Sodeland, S., & Barclay, L. (2012). Clinical and radiological investigation of thoracic spine extension motion during bilateral arm elevation. *Journal of Orthopaedic & Sports Physical Therapy, 42*(10), 861–869. https://doi.org/10.2519/jospt.2012.4164

Finucane, L. M., Downie, A., Mercer, C., Greenhalgh, S. M., Boissonnault, W. G., Pool-Goudzwaard, A. L., Beneciuk, J. M., Leech, R. L., & Selfe, J. (2020). International framework for red flags for potential serious spinal pathologies. *Journal of Orthopaedic & Sports Physical Therapy, 50*(7), 350–372. https://doi.org/10.2519/jospt.2020.9971

Minkalis, A. L., Vining, R. D., Long, C. R., Hawk, C., & de Luca, K. (2017). A systematic review of thrust manipulation for non-surgical shoulder conditions. *Chiropractic & Manual Therapies, 25*, 1. https://doi.org/10.1186/s12998-016-0133-8

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

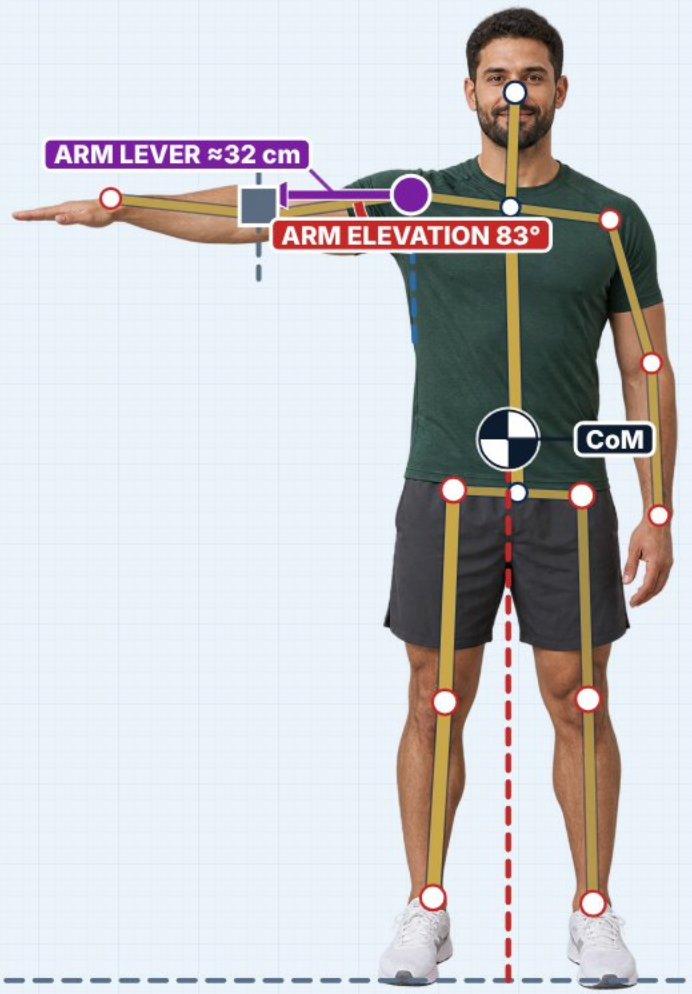
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BURSITIS: WHAT THE INFLAMED BURSA CAN AND CANNOT EXPLAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

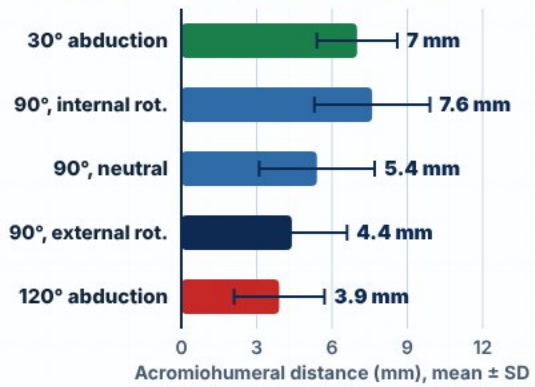
A · SIDE RAISE, FRONT



Side raise: the space narrows in everyone

- Arm raised to ≈**83°** with the elbow straight: arm lever ≈**32 cm**, shoulder moment ≈**11 N·m** for the cuff and deltoid to hold.
- The bursa sits in a space that roughly halves between 30° and 120° in every shoulder, so narrowing is normal mechanics, not proof of pinching.

Space under the acromion by position



3-D open MR imaging in volunteers; 120° vs 30° $p < 0.0001$. Graichen et al. (1999).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BURSITIS: WHAT THE INFLAMED BURSA CAN AND CANNOT EXPLAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

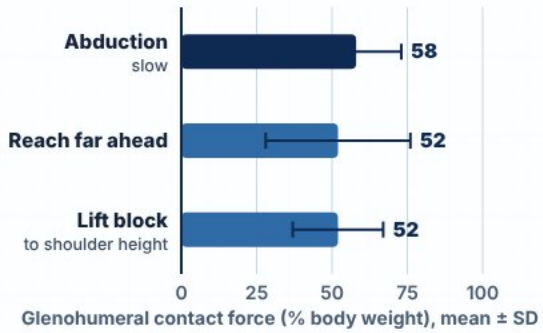
B · KETTLE AT ARM'S LENGTH, SIDE



Kettle at arm's length

- Arm reaching forward at ≈**52°** with a full kettle: the hand sits ≈**56 cm** in front of the joint, giving ≈**18 N·m** at the shoulder.
- Raising the arm to shoulder height or reaching far ahead puts about half of body weight through the joint, which is why these tasks often provoke subacromial pain.

Everyday reaches load the joint



25 adults, 26 daily tasks; musculoskeletal model estimates, not measured in the body. Klemt et al. (2018).

Key point: bring the load closer to the body to shorten the lever while the shoulder settles.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Full kettle assumed to weigh 1.5 kg. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BURSITIS: WHAT THE INFLAMED BURSA CAN AND CANNOT EXPLAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

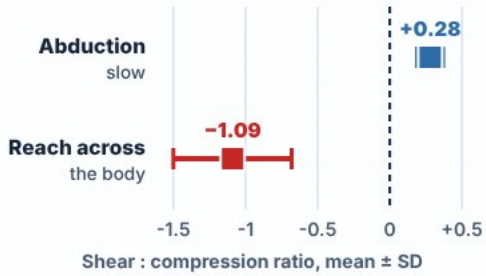
C · SEAT-BELT REACH, FRONT



Seat-belt reach: across the body

- Seated in the car, he reaches his arm across the chest to the seat belt at the opposite shoulder, a tight cross-body reach with the arm rotated.
- Reaching across the body produced the highest shear ratio of all 26 tasks studied, which may help explain why this small movement can sting.

Cross-body reach: the highest shear



Same 25 adults; negative = shear in the opposite direction; model estimates. Klemt et al. (2018).

Myth: "The scan shows bursitis, so that is the cause." Bursal fluid was seen in 16 of 45 pain-free dominant shoulders of overhead athletes (Ocguder et al., 2010).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Twisted seated reach: pose landmarks are unreliable here, so no angles are quoted. Educational, not diagnostic.

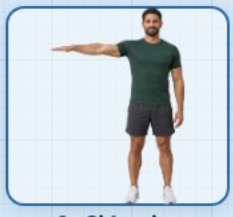
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER BURSITIS: WHAT THE INFLAMED BURSA CAN AND CANNOT EXPLAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Side raise
≈11 N·m

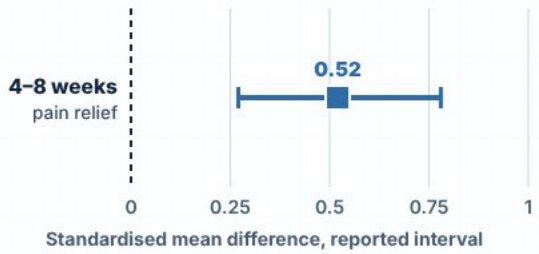


B · Kettle
≈18 N·m



C · Seat belt
Highest shear

Injecting the bursa: small, short relief



11 RCTs, 726 adults with rotator cuff tendinosis; no reduction in pain at 3 months; at least 5 must be treated for one to gain transient relief. Mohamadi et al. (2017).

Decision pathway

1. **EXPLAIN**
   Bursal changes are common in pain-free shoulders; diagnose from the whole clinical picture.
2. **LOAD**
   Start education and progressive exercise; shorten levers on painful reaches meanwhile.
3. **OPTION**
   If no better by 6–8 weeks, consider one injection to enable exercise; refer by 12 weeks.

NOT RECOMMENDED

First-line decompression or bursectomy; repeated injections.

SEEK ASSESSMENT IF

A hot, red, swollen shoulder with fever, especially after an injection or if immunosuppressed; suspected fracture or dislocation; a lump; several inflamed joints.

REFERENCES (APA 7)

Beard, D. J., Rees, J. L., Cook, J. A., Rombach, I., Cooper, C., Merritt, N., Shirkey, B. A., Donovan, J. L., Gwilym, S., Savulescu, J., Moser, J., Gray, A., Jepson, M., Tracey, I., Judge, A., Wartolowska, K., Carr, A. J., Ahrens, P., Baldwick, C., Brinsden, M., ... CSAW Study Group. (2018). Arthroscopic subacromial decompression for subacromial shoulder pain (CSAW): A multicentre, pragmatic, parallel group, placebo-controlled, three-group, randomised surgical trial. *The Lancet, 391*(10118), 329–338. https://doi.org/10.1016/S0140-6736(17)32457-1

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Graichen, H., Bonel, H., Stammberger, T., Englmeier, K.-H., Reiser, M., & Eckstein, F. (1999). Subacromial space width changes during abduction and rotation: A 3-D MR imaging study. *Surgical and Radiologic Anatomy, 21*(1), 59–64. https://doi.org/10.1007/BF01635055

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Mohamadi, A., Chan, J. J., Claessen, F. M., Ring, D., & Chen, N. C. (2017). Corticosteroid injections give small and transient pain relief in rotator cuff tendinosis: A meta-analysis. *Clinical Orthopaedics and Related Research, 475*(1), 232–243. https://doi.org/10.1007/s11999-016-5002-1

Ocguder, D. A., Tosun, O., Bektaser, B., Cicek, N., Ipek, A., & Bozkurt, M. (2010). Ultrasonographic evaluation of the shoulder in asymptomatic overhead athletes. *Acta Orthopaedica Belgica, 76*(4).

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

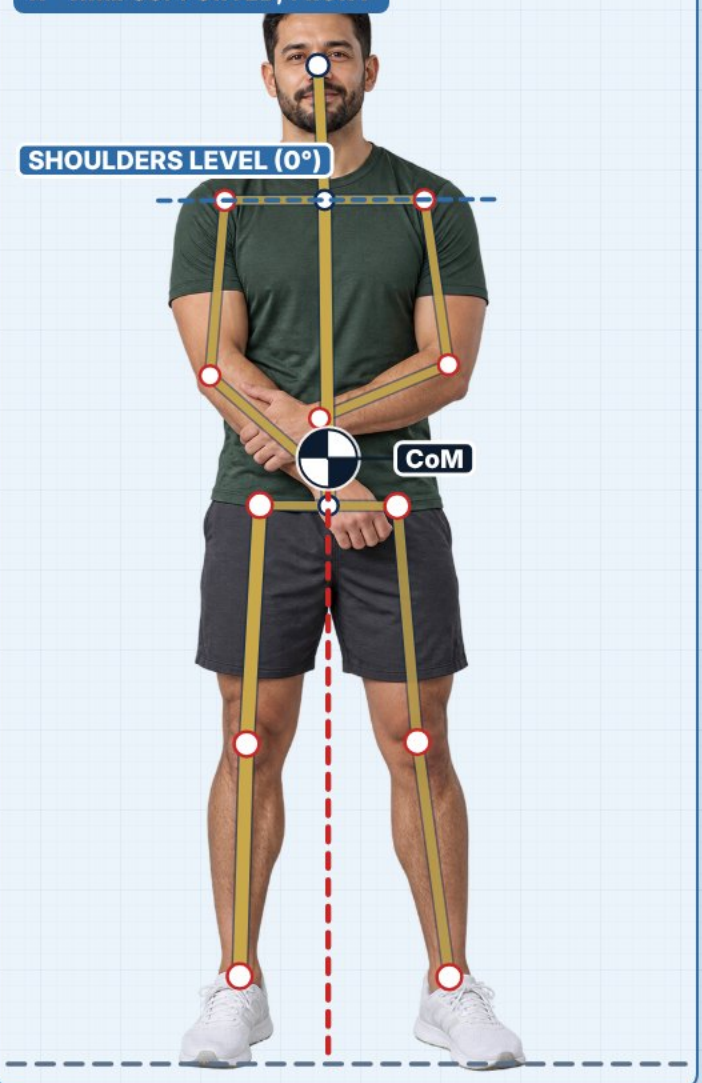
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CALCIFIC TENDINITIS: SUDDEN SEVERE SHOULDER PAIN AND WHAT HELPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

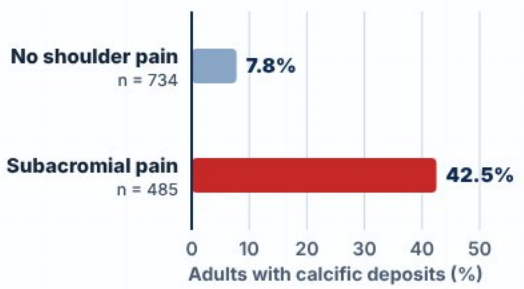
A · ARM SUPPORTED, FRONT



The acute flare: protect and settle

- Forearms held across the stomach, the painful arm supported by the other hand, shoulders level (**0°**): the typical guarding posture of a very painful shoulder.
- Calcium deposits, most often in the supraspinatus tendon, can be painless; severe flares often occur as a deposit breaks down.

Deposits: common with pain, present without



1219 adults, clinical and radiological data. Louwerens et al. (2015).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

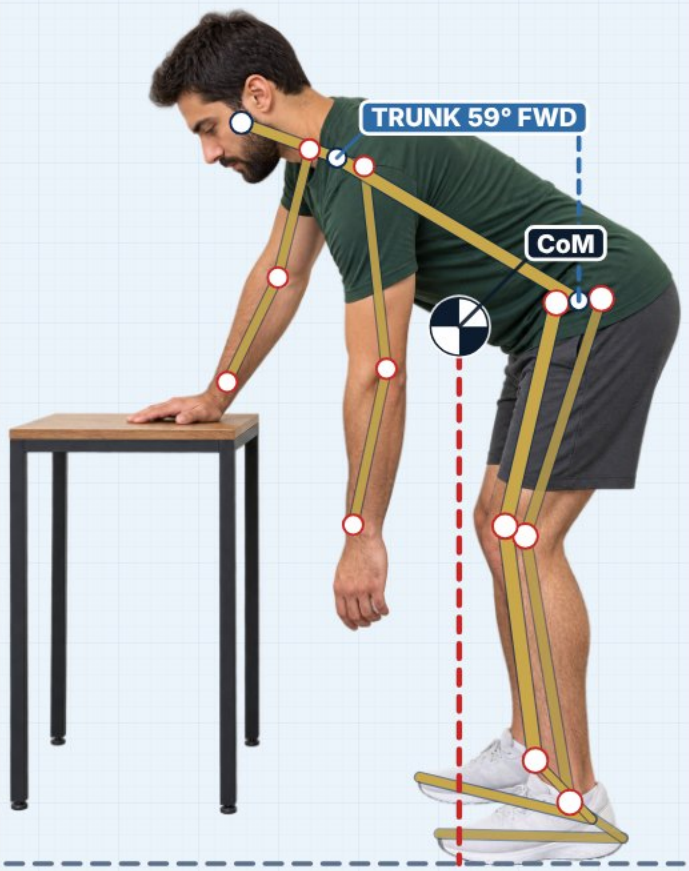
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CALCIFIC TENDINITIS: SUDDEN SEVERE SHOULDER PAIN AND WHAT HELPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

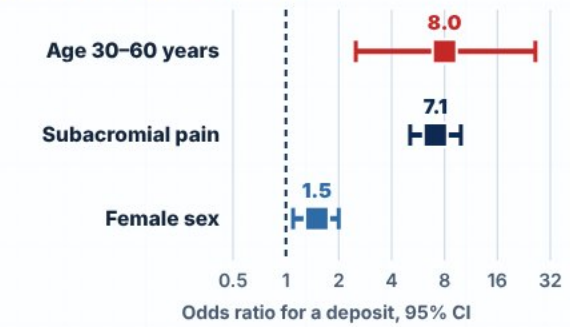
B · PENDULUM CIRCLES, SIDE



Pendulum: movement without effort

- One hand on the table, trunk ≈**59°** forward, the other arm hanging and making small circles: gravity does the work, so the cuff stays relaxed.
- Deposits were most strongly associated with age 30–60 and with subacromial pain; women were slightly more often affected.

Who has calcific deposits?



Same 1219 adults; associations, not causes. Louwerens et al. (2015).

Key point: in an acute flare, gentle pendular and assisted movement as tolerated keeps the shoulder moving.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk line from hip to shoulder points in the side view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CALCIFIC TENDINITIS: SUDDEN SEVERE SHOULDER PAIN AND WHAT HELPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

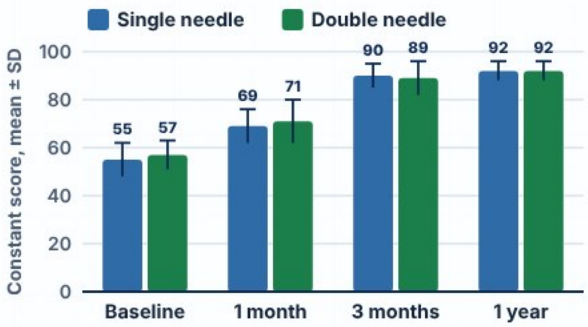
C · ASSISTED ARM RAISE, SIDE



Assisted raise: range without strain

- Lying on the back, the arm is lifted overhead with help from the other hand, so range is regained while the painful tendon does little work.
- After ultrasound-guided lavage, most of the recovery in this series came within 3 months; without an untreated group, it shows the course, not the effect.

After lavage: most gain by 3 months



211 patients, US-guided lavage plus intrabursal steroid; techniques did not differ (P = .241); post-procedure bursitis in 9% and 3.6%. Orlandi et al. (2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable lying down, so no angles are quoted for this frame. Educational, not diagnostic.

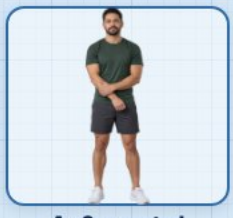
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CALCIFIC TENDINITIS: SUDDEN SEVERE SHOULDER PAIN AND WHAT HELPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Supported
Protect the flare

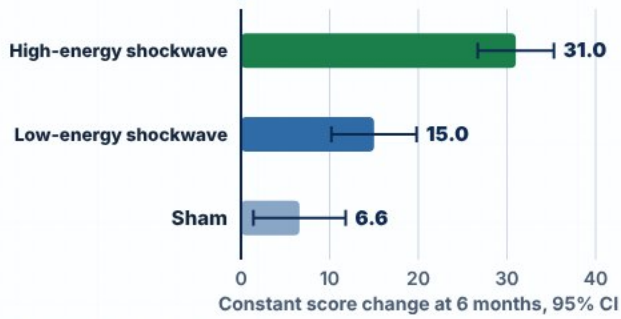


B · Pendulum
Trunk ≈59°



C · Assisted raise
Regain range

Persistent calcific pain: shockwave dose



144 patients, double-blind placebo-controlled trial; both doses beat sham and high beat low (P < .001). Gerdesmeyer et al. (2003).

Decision pathway

1. **SETTLE**
   In a flare, rest the arm in a comfortable position, use simple pain relief, then gentle assisted movement.
2. **CONFIRM**
   X-ray or ultrasound confirms a deposit; match it to the symptoms, as many are painless.
3. **ESCALATE**
   If pain persists, discuss high-energy shockwave or lavage with steroid; surgery is for refractory cases.

NOT RECOMMENDED

Shockwave for cuff pain without a calcific deposit; surgery before non-surgical options.

SEEK ASSESSMENT IF

Rapidly escalating pain with fever, redness or heat; pain after injury; or pain that stops all movement or sleep.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

de Witte, P. B., Selten, J. W., Navas, A., Nagels, J., Visser, C. P., Nelissen, R. G., & Reijnierse, M. (2013). Calcific tendinitis of the rotator cuff: A randomized controlled trial of ultrasound-guided needling and lavage versus subacromial corticosteroids. *American Journal of Sports Medicine, 41*(7), 1665–1673. https://doi.org/10.1177/0363546513487066

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Gerdesmeyer, L., Wagenpfeil, S., Haake, M., Maier, M., Loew, M., Wörtler, K., Lampe, R., Seil, R., Handle, G., Gassel, S., & Rompe, J. D. (2003). Extracorporeal shock wave therapy for the treatment of chronic calcifying tendonitis of the rotator cuff: A randomized controlled trial. *JAMA, 290*(19), 2573–2580. https://doi.org/10.1001/jama.290.19.2573

Louwerens, J. K. G., Sierevelt, I., van Hove, R., van den Bekerom, M., & van Noort, A. (2015). Prevalence of calcific deposits within the rotator cuff tendons in adults with and without subacromial pain syndrome: Clinical and radiologic analysis of 1219 patients. *Journal of Shoulder and Elbow Surgery, 24*(10), 1588–1593.

Orlandi, D., Mauri, G., Lacelli, F., Corazza, A., Messina, C., Silvestri, E., Serafini, G., & Sconfienza, L. M. (2017). Rotator cuff calcific tendinopathy: Randomized comparison of US-guided percutaneous treatments by using one or two needles. *Radiology, 285*(2), 518–527. https://doi.org/10.1148/radiol.2017162888

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LONG HEAD OF BICEPS PAIN: PAIN AT THE FRONT OF THE SHOULDER

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

A · BAG ON BENT ELBOW, SIDE



Carrying on a bent elbow

- Heavy bag held with the elbow flexed ≈**74°** in front of the body: the biceps holds the load, so its long-head tendon at the front of the shoulder is under tension.
- With the elbow and forearm braced, the long head showed no electrical activity during shoulder movement, even with a weight added.

Arm raising alone did not activate it

Shoulder motion, elbow braced	LHB EMG activity
Full-arc motion, slow 36°/s	None identified
Full-arc motion, fast 170°/s	None identified
Same motions + 2.3 kg 5-lb weight on the brace	None identified

10 shoulders, dynamic EMG with the elbow and forearm immobilised. Levy et al. (2001).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow flexion angle from pose landmarks in the side view. Educational, not diagnostic.

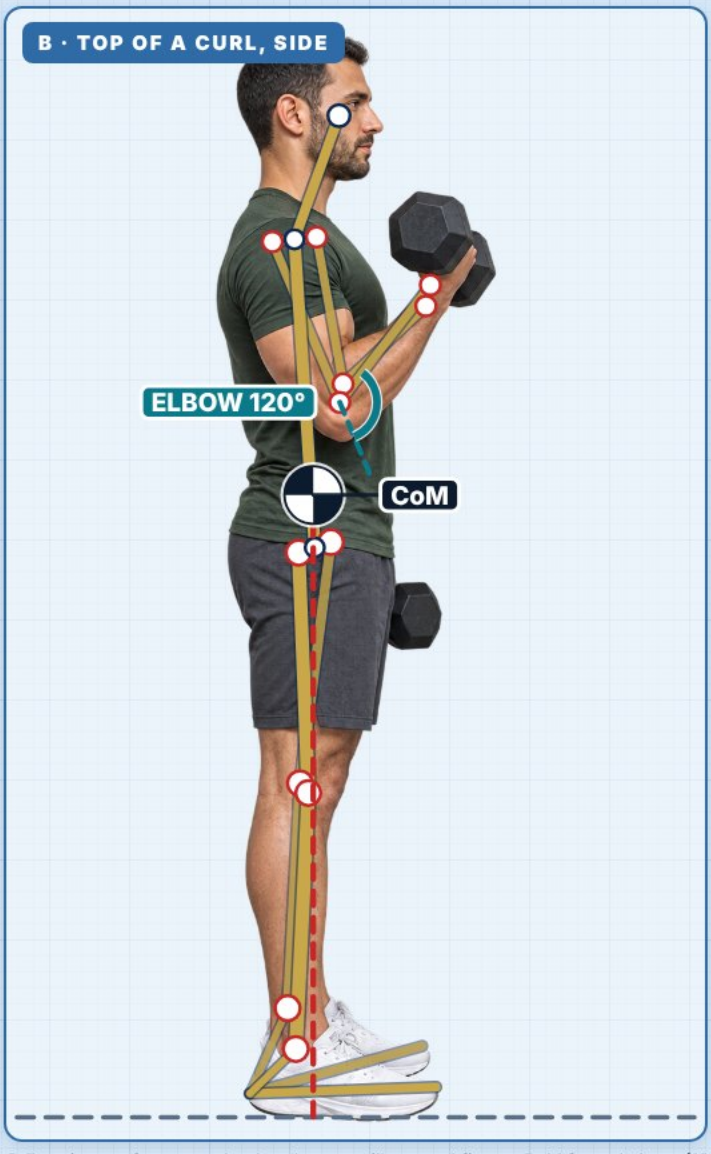
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LONG HEAD OF BICEPS PAIN: PAIN AT THE FRONT OF THE SHOULDER

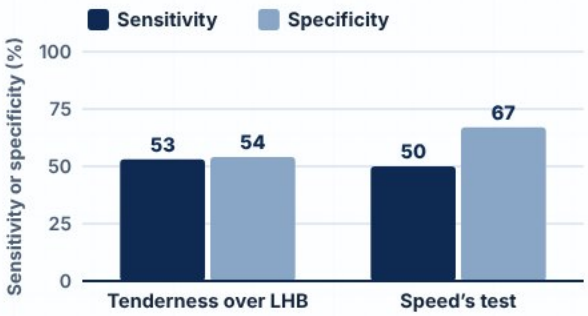
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Top of the curl: elbow flexion load

- Dumbbell curled up with the elbow at ≈**120°** of flexion and the upper arm by the side: elbow flexion and forearm supination are the long head's main jobs.
- Clinical tests alone are unreliable: tenderness and Speed's test each detected only about half of partial tears found at arthroscopy.

Tests miss about half of tears



847 consecutive arthroscopies; 40 patients (about 5%) had partial LHB tears, most with cuff tears. Gill et al. (2007).

Key point: elbow-flexion load is a useful dial: lighten curls and bent-elbow carries while the tendon settles.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow flexion angle from pose landmarks in the side view. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LONG HEAD OF BICEPS PAIN: PAIN AT THE FRONT OF THE SHOULDER

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

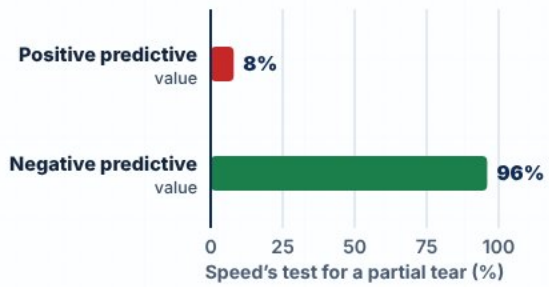
C · HANDS BEHIND BACK, SIDE



Hands behind the back

- Hands clasped behind the back, arms straight and lifted ≈**33°** behind the trunk: shoulder extension stretches the long head across the front of the joint.
- A positive Speed's test was right only 8% of the time; a negative one made a partial tear unlikely, partly because tears were uncommon.

What a Speed's test result means



Same 847 patients; LR+ 1.51. Gill et al. (2007).

Myth: "A positive Speed's test means a biceps tear." Read front-of-shoulder pain as a pattern, not one test.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm angle: upper arm relative to the trunk line, here measured behind the body. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

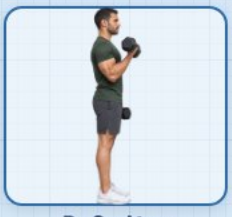
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LONG HEAD OF BICEPS PAIN: PAIN AT THE FRONT OF THE SHOULDER

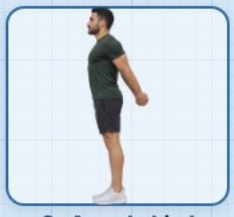
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Bent-elbow carry
Elbow ≈74°

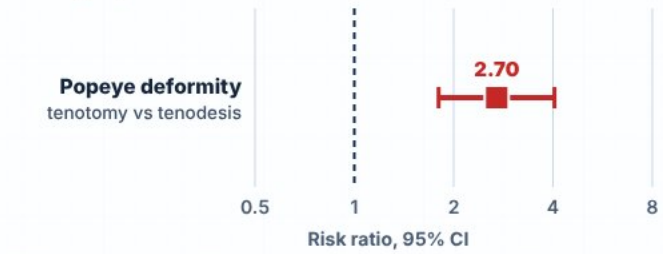


B · Curl top
Elbow ≈120°



C · Arms behind
Extension stretch

If surgery: function similar, looks differ



2 RCTs and 5 cohorts (288 tenotomy, 303 tenodesis) with cuff repair; Constant score difference only −1.09 points. Na et al. (2019).

Decision pathway

1. **MODIFY**
   Reduce provoking bent-elbow carrying, curls and supination while symptoms settle.
2. **LOAD**
   Progress cuff, shoulder-blade and elbow-flexor strength; exercise is first line for cuff-related pain.
3. **CONSIDER**
   Injection or surgery only for persistent, function-limiting pain; options differ mainly in appearance.

NOT RECOMMENDED

Relying on a single test such as Speed's to diagnose a tear.

SEEK ASSESSMENT IF

A sudden "pop" with bruising and a lump in the upper arm, sudden weakness lifting the arm after injury, or suspected fracture, infection or a lump.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Gill, H. S., El Rassi, G., Bahk, M. S., Castillo, R. C., & McFarland, E. G. (2007). Physical examination for partial tears of the biceps tendon. *American Journal of Sports Medicine, 35*(8), 1334–1340.

Levy, A. S., Kelly, B. T., Lintner, S. A., Osbahr, D. C., & Speer, K. P. (2001). Function of the long head of the biceps at the shoulder: Electromyographic analysis. *Journal of Shoulder and Elbow Surgery, 10*(3), 250–255. https://doi.org/10.1067/mse.2001.113087

Na, Y., Zhu, Y., Shi, Y., Ren, Y., Zhang, T., Liu, W., & Han, C. (2019). A meta-analysis comparing tenotomy or tenodesis for lesions of the long head of the biceps tendon with concomitant reparable rotator cuff tears. *Journal of Orthopaedic Surgery and Research, 14*, 1–8. https://doi.org/10.1186/s13018-019-1429-x

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

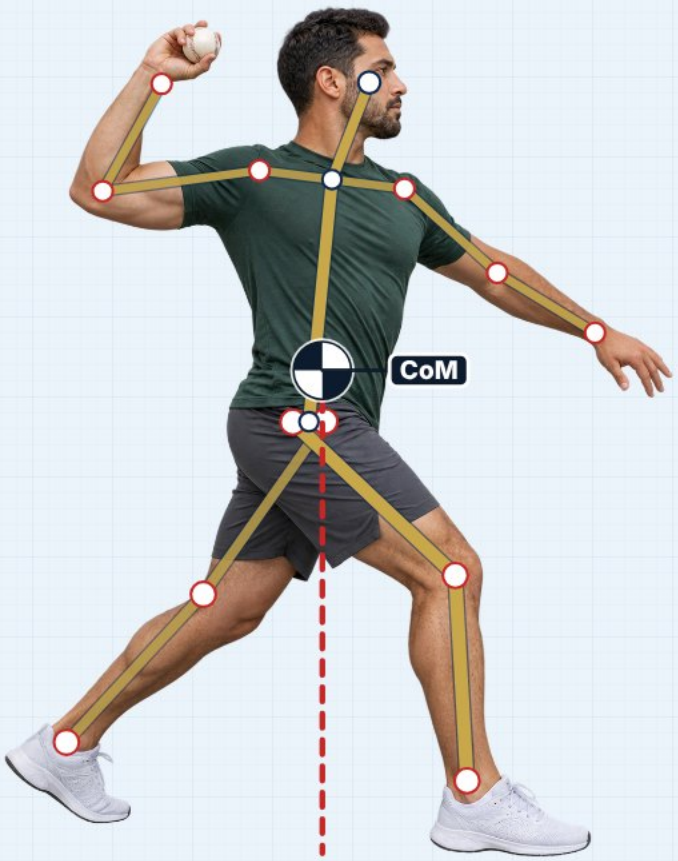
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LABRAL TEAR (SLAP): CLICKING, CATCHING AND DEEP SHOULDER PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

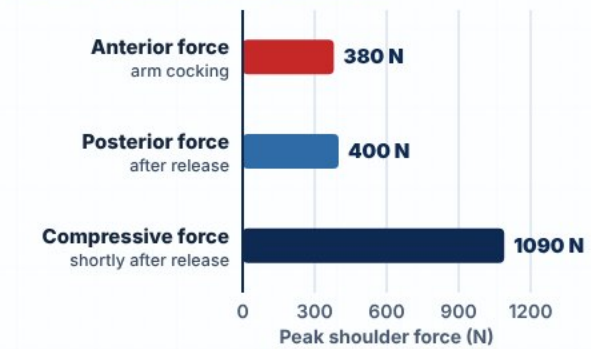
A · THROWING ARM COCKED, SIDE



Late cocking: the labrum under strain

- Ball held behind the head, elbow at about shoulder height, stride leg forward: the arm is near maximal external rotation, a proposed position for peeling the superior labrum.
- In skilled pitchers, internal rotation torque peaked at 67 N·m just before maximal external rotation, with large forces after release as the arm decelerates.

Pitching loads on the shoulder



26 highly skilled adult pitchers, high-speed motion analysis with inverse dynamics. Fleisig et al. (1995).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Twisted throwing pose: pose landmarks are unreliable here, so no angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

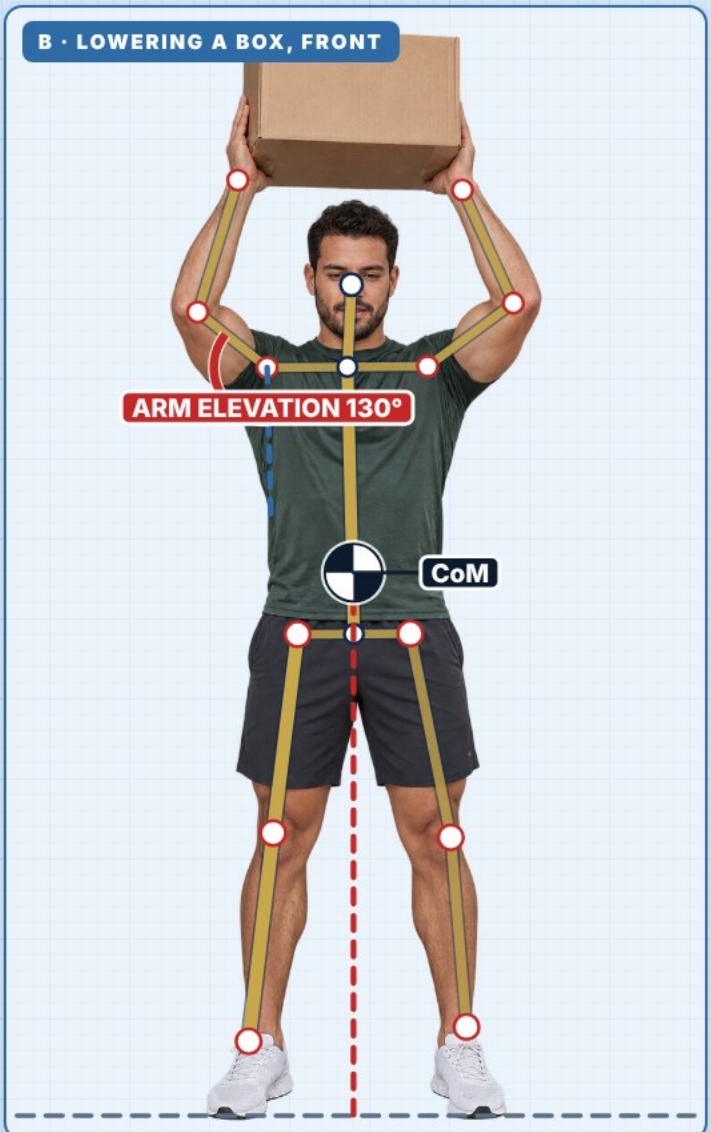
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LABRAL TEAR (SLAP): CLICKING, CATCHING AND DEEP SHOULDER PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

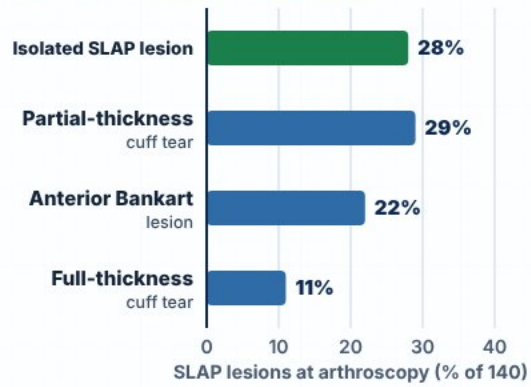
B · LOWERING A BOX, FRONT



Overhead lowering: a far lighter load

- Box held overhead in both hands, arms at ≈**130°**, before lowering it: an everyday end-range load, far below throwing forces, that can still provoke deep pain.
- In 140 arthroscopic cases, only 28% of SLAP lesions were isolated; most came with cuff or Bankart damage, so deep pain may not come from the labrum alone.

Most SLAP lesions are not alone



140 superior labral injuries; type II was most common (55%); mean age 38, 91% men. Snyder et al. (1995).

Myth: "Clicking means a tear that needs repair." Catching or grinding was reported by only 49% with confirmed lesions.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation from pose landmarks in the front view; box weight not known, so no moment is quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LABRAL TEAR (SLAP): CLICKING, CATCHING AND DEEP SHOULDER PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

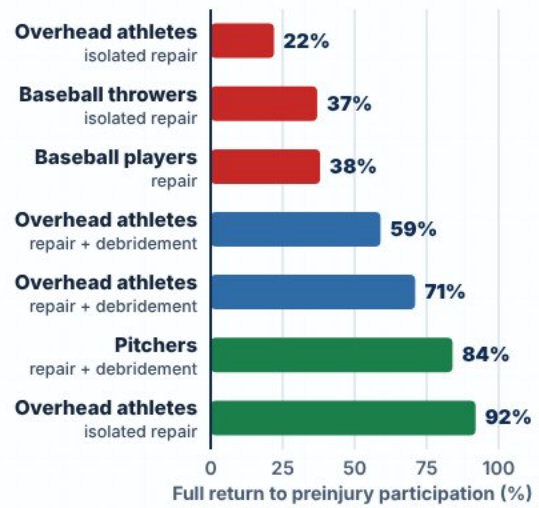
C · PUSH-UP, LOWEST POINT, SIDE



Push-up depth: end-range control

- Chest just above the floor, elbows bent ≈**106°**, body straight: the shoulder is loaded at the end of its extension range, a useful closed-chain test of control.
- After superior labral repair in overhead athletes, full return to preinjury sport varied from 22% to 92%, least predictable in baseball players.

Return to sport after SLAP repair



One cohort per bar, as compiled in a systematic review of 11 studies, overhead athletes aged 40 or under. Sciascia et al. (2015).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow flexion angle from pose landmarks; other angles are unreliable in push-ups and are not quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

LABRAL TEAR (SLAP): CLICKING, CATCHING AND DEEP SHOULDER PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Cocked arm
Peak torque

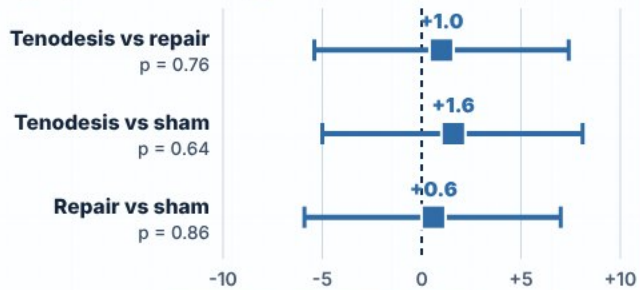


B · Box overhead
Arms ≈130°



C · Push-up
Elbow ≈106°

Surgery vs sham for type II SLAP



118 surgical candidates, mean age 40, double-blind; stiffness after repair (5) and tenodesis (4). Schrøder et al. (2017).

Decision pathway

1. **MATCH**
   Match a scan finding to the history and examination, as labral changes often coexist with other damage.
2. **REHAB**
   Start with cuff and shoulder-blade strength, range including the back of the shoulder, then graded throwing.
3. **DISCUSS**
   If surgery is considered, set realistic return-to-sport expectations, especially for throwers.

NOT RECOMMENDED

Surgery as the first step for a type II SLAP lesion in most people.

SEEK ASSESSMENT IF

A shoulder that dislocated, sudden loss of strength, locking that blocks movement, symptoms after a high-energy fall, or persistent deep pain or lost velocity in a thrower.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Fleisig, G. S., Andrews, J. R., Dillman, C. J., & Escamilla, R. F. (1995). Kinetics of baseball pitching with implications about injury mechanisms. *American Journal of Sports Medicine, 23*(2), 233–239. https://doi.org/10.1177/036354659502300218

Schrøder, C. P., Skare, Ø., Reikerås, O., Mowinckel, P., & Brox, J. I. (2017). Sham surgery versus labral repair or biceps tenodesis for type II SLAP lesions of the shoulder: A three-armed randomised clinical trial. *British Journal of Sports Medicine, 51*(24), 1759–1766. https://doi.org/10.1136/bjsports-2016-097098

Sciascia, A., Myers, N., Kibler, W. B., & Uhl, T. L. (2015). Return to preinjury levels of participation after superior labral repair in overhead athletes: A systematic review. *Journal of Athletic Training, 50*(7), 767–777. https://doi.org/10.4085/1062-6050-50.3.06

Snyder, S. J., Banas, M. P., & Karzel, R. P. (1995). An analysis of 140 injuries to the superior glenoid labrum. *Journal of Shoulder and Elbow Surgery, 4*(4), 243–248. https://doi.org/10.1016/S1058-2746(05)80015-1

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

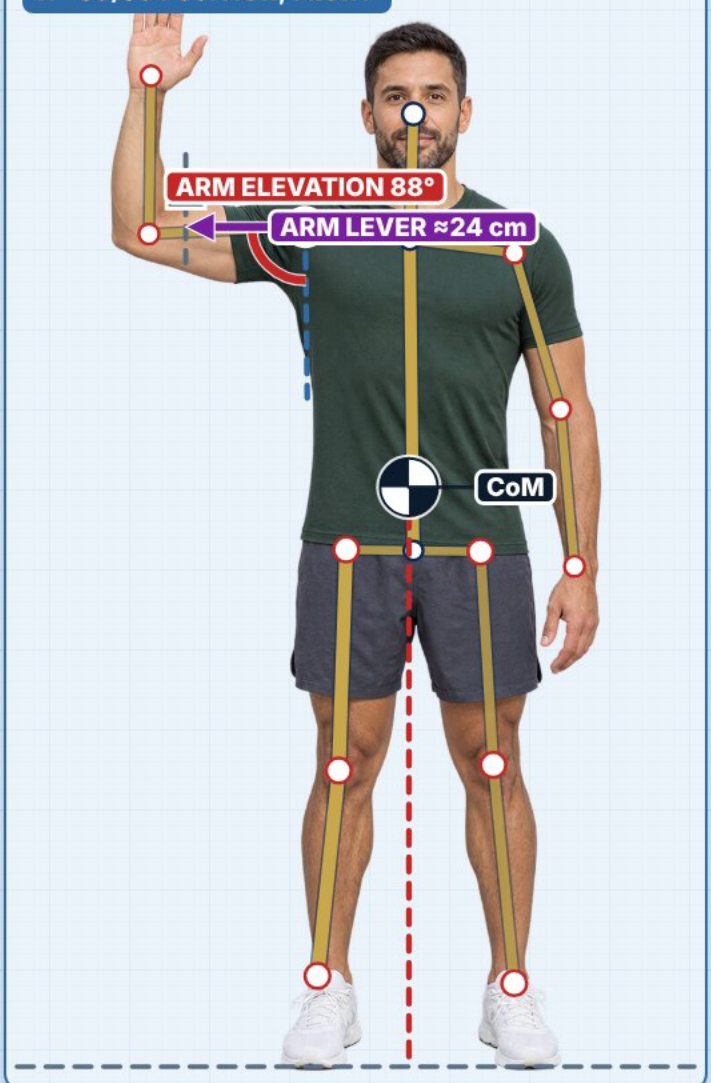
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER DISLOCATION: WHAT HAPPENS TO THE JOINT, AND THE RISK OF IT HAPPENING AGAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

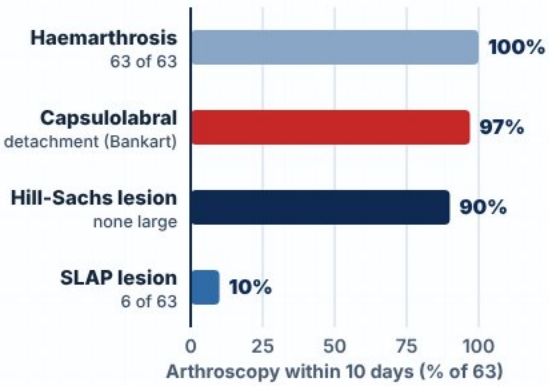
A · 90/90 POSITION, FRONT



The 90/90 position: where it happens

- Arm out at ≈**88°**, elbow bent, hand pointing up: abduction with external rotation is the typical position for a forward dislocation; arm lever ≈**24 cm**, shoulder moment ≈**8 N·m**.
- In young people a first dislocation is rarely "just a slip": nearly all tore the front of the labrum and capsule, and most dented the humeral head.

Inside the joint after a first dislocation



Patients under 24 years after a first traumatic anterior dislocation; 48 of 53 managed without surgery had recurrent instability. Taylor & Arciero (1997).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER DISLOCATION: WHAT HAPPENS TO THE JOINT, AND THE RISK OF IT HAPPENING AGAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

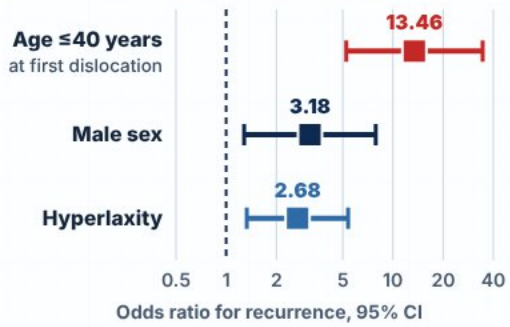
B · HIGH PLANK, SIDE



High plank: closed-chain control

- On straight arms with the body in a line from head to heels: the hands are fixed, so the cuff and shoulder-blade muscles steady the joint under body weight.
- Pooled recurrence was 39%. Younger age, male sex and general laxity were associated with recurrence; a greater tuberosity fracture with lower risk.

Who is more likely to dislocate again?



10 studies, 1324 adults after a first traumatic anterior dislocation; recurrence 44% at ≤40 vs 11% over 40. Olds et al. (2015).

Key point: these are associations that guide the conversation about surgery, not certainties for one person.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in plank positions, so no angles are quoted for this frame. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

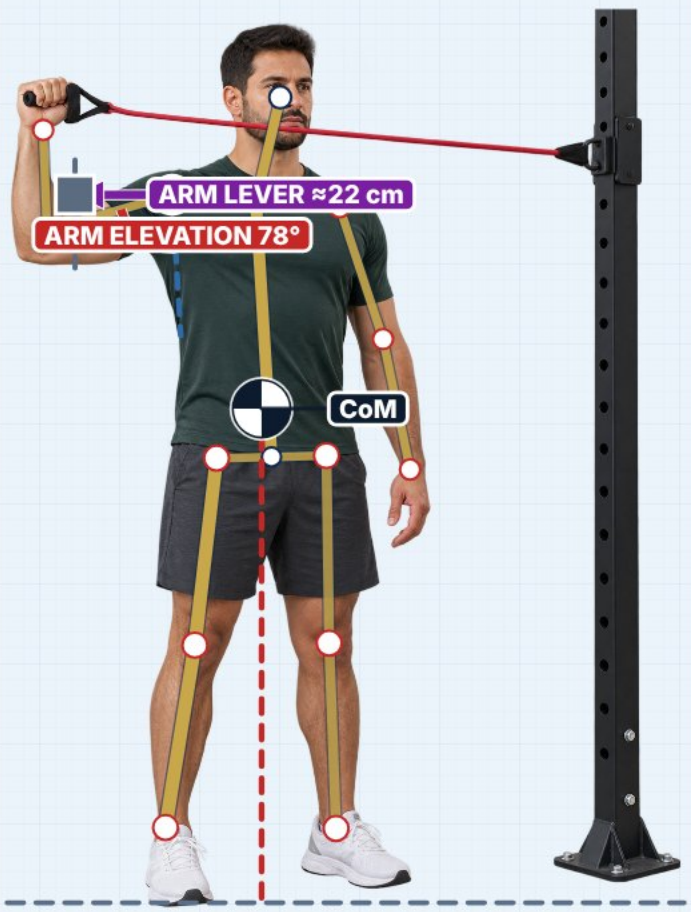
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER DISLOCATION: WHAT HAPPENS TO THE JOINT, AND THE RISK OF IT HAPPENING AGAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

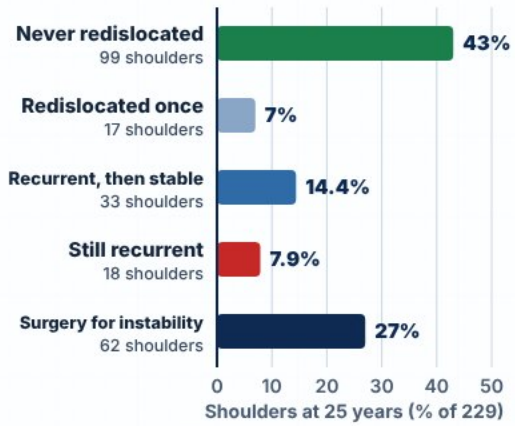
C · BAND ROTATION 90/90, FRONT



Band rotation at 90/90

- Arm at ≈**78°** with the elbow bent, rotating the forearm up against a band: strength in the position where dislocation happens, built gradually.
- Over 25 years after non-surgical care, 43% of shoulders never dislocated again, and some recurrent shoulders became stable with time.

The 25-year course without surgery



229 shoulders, aged 12–40 at first dislocation, prospective multicentre cohort; all living patients followed up. Hovelius et al. (2008).

Myth: "Once you have dislocated, you will always need surgery." Many shoulders stay stable.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Band tension not included. Educational, not diagnostic.

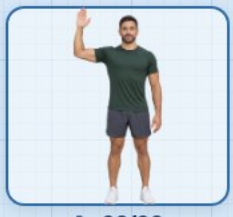
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER DISLOCATION: WHAT HAPPENS TO THE JOINT, AND THE RISK OF IT HAPPENING AGAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · 90/90
Arm ≈88°

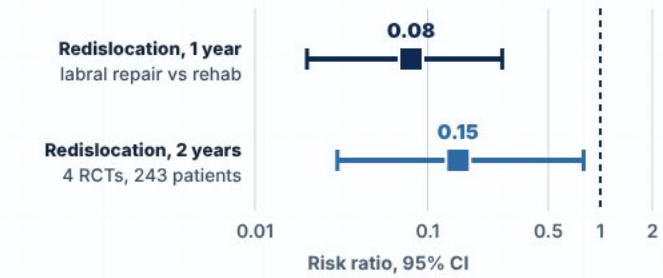


B · High plank
Closed chain



C · Band rotation
≈7 N·m arm only

Repair vs rehabilitation after a first dislocation



Network meta-analysis of 22 RCTs; 47% managed without surgery did not redislocate by 2 years; moderate certainty. Kavaja et al. (2018).

Decision pathway

1. **REDUCE**
   Urgent care: x-ray before and after reduction, with a nerve and circulation check.
2. **REHAB**
   Progress from protected range to cuff and shoulder-blade strength, plank control and 90/90 work.
3. **DECIDE**
   Discuss early repair with young people in contact or overhead sport, weighing laxity and bone loss.

NOT RECOMMENDED

Assuming the shoulder is fine once it is back in, or that surgery is always needed.

SEEK ASSESSMENT IF

A shoulder that will not go back or keeps slipping, numbness or weakness of the deltoid or arm, or inability to lift the arm after reduction (especially over 40).

REFERENCES (APA 7)

Brownson, P., Donaldson, O., Fox, M., Rees, J. L., Rangan, A., Jaggi, A., Tytherleigh-Strong, G., McBernie, J., Thomas, M., & Kulkarni, R. (2015). BESS/BOA patient care pathways: Traumatic anterior shoulder instability. *Shoulder & Elbow, 7*(3), 214–226. https://doi.org/10.1177/1758573215585656

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hovelius, L., Olofsson, A., Sandström, B., Augustini, B.-G., Krantz, L., Fredin, H., Tillander, B., Skoglund, U., Salomonsson, B., Nowak, J., & Sennerby, U. (2008). Nonoperative treatment of primary anterior shoulder dislocation in patients forty years of age and younger: A prospective twenty-five-year follow-up. *Journal of Bone and Joint Surgery (American Volume), 90*, 945–952. https://doi.org/10.2106/JBJS.G.00070

Kavaja, L., Lähdeoja, T., Malmivaara, A., & Paavola, M. (2018). Treatment after traumatic shoulder dislocation: A systematic review with a network meta-analysis. *British Journal of Sports Medicine, 52*(23), 1498–1506. https://doi.org/10.1136/bjsports-2017-098539

Olds, M., Ellis, R., Donaldson, K., Parmar, P., & Kersten, P. (2015). Risk factors which predispose first-time traumatic anterior shoulder dislocations to recurrent instability in adults: A systematic review and meta-analysis. *British Journal of Sports Medicine, 49*(14), 913–922. https://doi.org/10.1136/bjsports-2014-094342

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Taylor, D. C., & Arciero, R. A. (1997). Pathologic changes associated with shoulder dislocations: Arthroscopic and physical examination findings in first-time, traumatic anterior dislocations. *American Journal of Sports Medicine, 25*(3), 306–311. https://doi.org/10.1177/036354659702500306

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

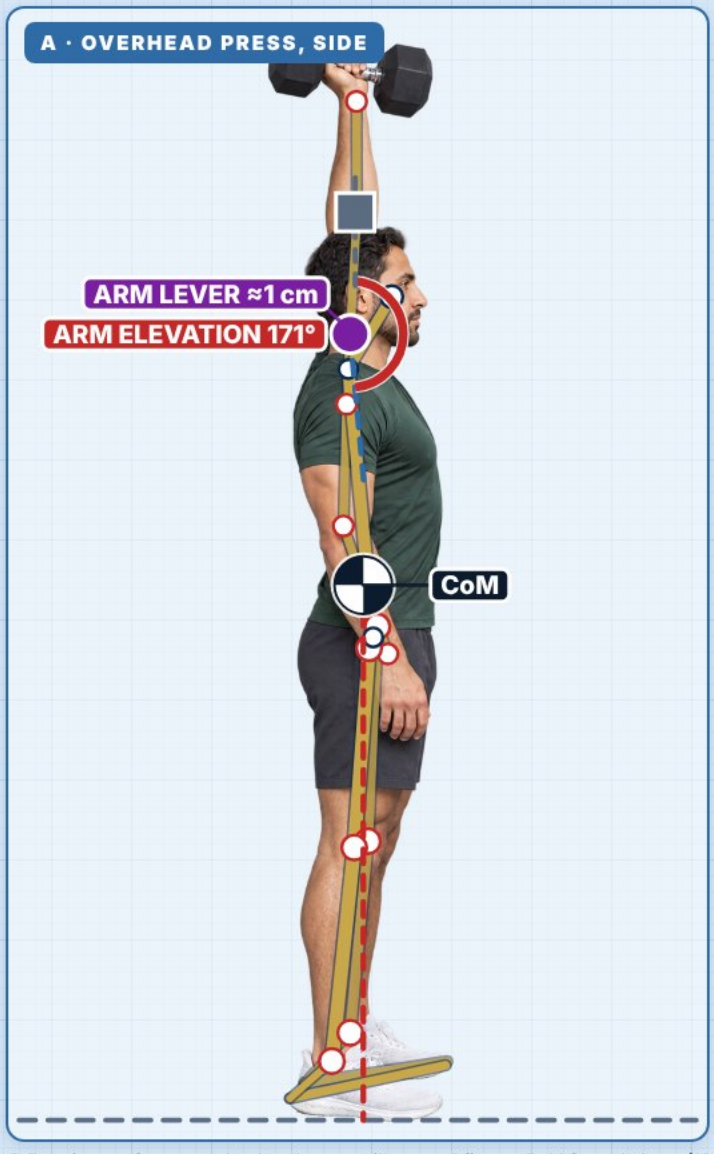
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INSTABILITY: WHEN THE SHOULDER FEELS LOOSE OR SLIPS

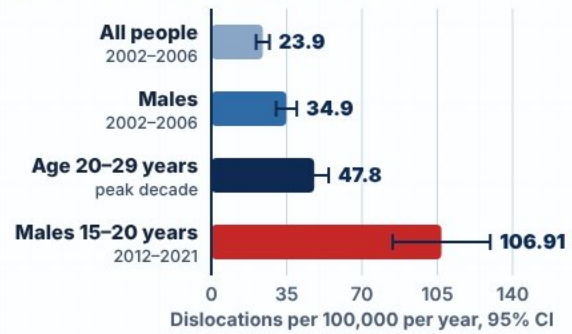
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Overhead: small lever, stressed restraints

- Arm elevated **171°**: the arm's weight sits almost over the joint (lever ≈**1 cm**), so the cuff holds little moment; the challenge is control, not effort.
- Instability means symptomatic slipping of the humeral head, from a partial slip (subluxation) to a full dislocation; after a first traumatic dislocation the main problem is recurrence.

Who dislocates? Young males



US emergency departments; 71.8% of dislocations in males (2002–2006). Zacchilli & Owens (2010); Patrick et al. (2023).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

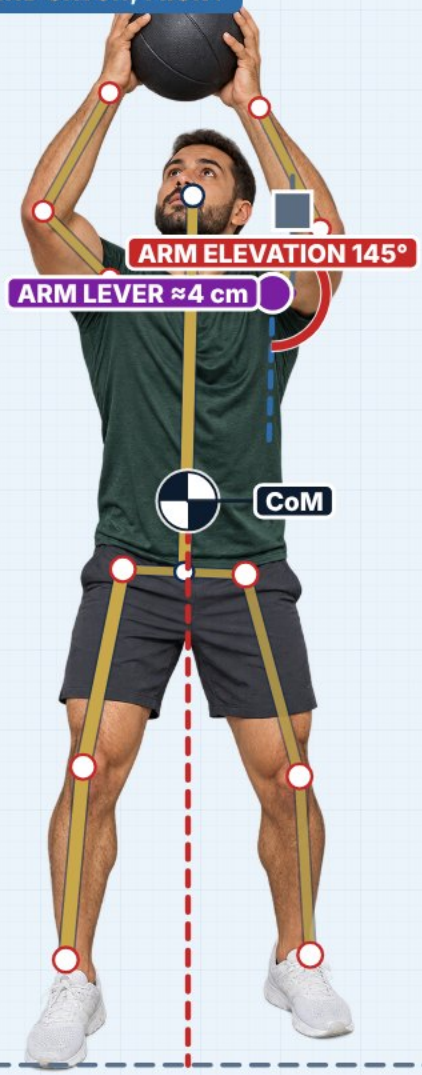
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INSTABILITY: WHEN THE SHOULDER FEELS LOOSE OR SLIPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

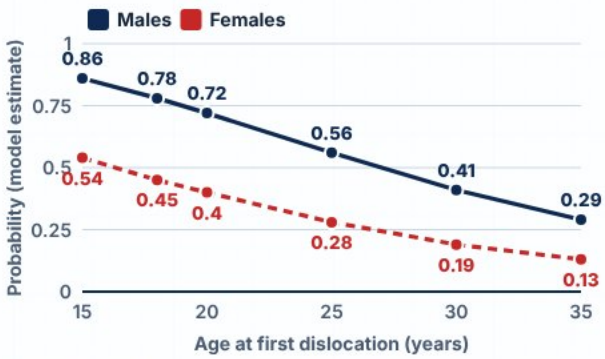
B · OVERHEAD CATCH, FRONT



Catching above the head

- Arms at **145°** with a lever of **≈4 cm**: a light load, but a sudden catch at end range asks the shoulder to control the head of the humerus quickly.
- Age at the first dislocation is the strongest marker of risk: younger people, especially males, are far more likely to slip again within two years.

Recurrence within 2 years by age



Model estimates for young patients after a first traumatic anterior dislocation (Robinson model, reproduced in Table 1). Brownson et al. (2015).

Key point: pooled recurrence after a first traumatic dislocation was 39% across 10 studies (Olds et al., 2015).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

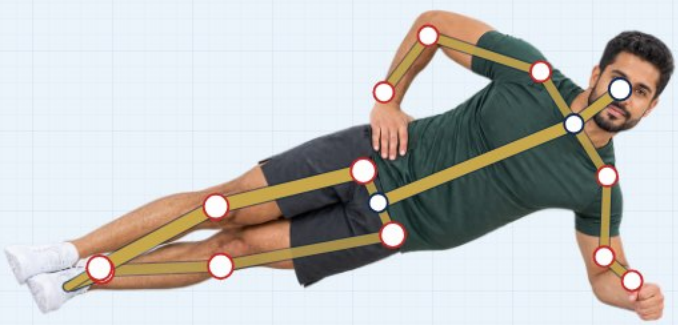
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INSTABILITY: WHEN THE SHOULDER FEELS LOOSE OR SLIPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

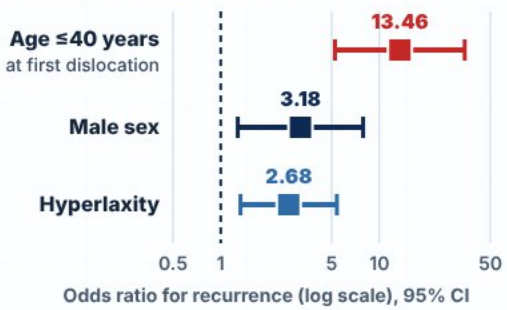
C · SIDE PLANK, FRONT



Closed-chain stability work

- Side plank loads the shoulder through the forearm with the joint compressed, a common way to build cuff and shoulder-blade control before faster overhead work.
- Younger age, male sex and generalised laxity are associated with recurrence; a greater tuberosity fracture is associated with lower recurrence (association, not cause).

What is linked to slipping again?



10 studies, 1,324 adults; recurrence 44% at ≤40 vs 11% at >40 years. Olds et al. (2015).

Myth: "Weeks in a sling will tighten it up." Immobilisation beyond 1 week does not reduce recurrence (Brownson et al., 2015).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose angles are unreliable in this lying position. Educational, not diagnostic.

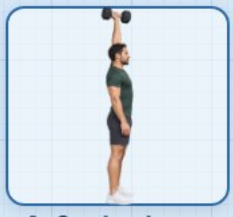
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INSTABILITY: WHEN THE SHOULDER FEELS LOOSE OR SLIPS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Overhead press
Lever ≈1 cm

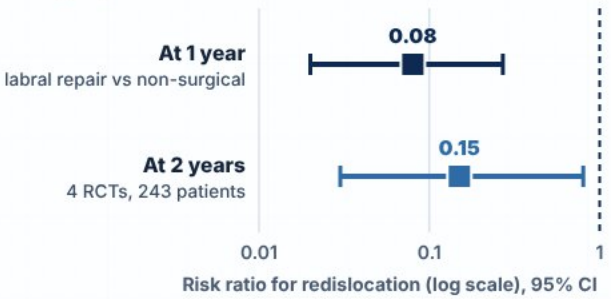


B · Overhead catch
145° elevation



C · Side plank
Closed-chain control

Surgery lowers redislocation



Yet 47% managed without surgery had not redislocated by 2 years; moderate certainty. Kavaja et al. (2018).

Decision pathway

1. **DECIDE**
   Weigh age, sex, sport and laxity in a shared decision; repair is supported for young males in contact or overhead sport.
2. **LOAD**
   Mobilise early; progress cuff and shoulder-blade loading, closed-chain stability, then overhead and catching tasks.
3. **REVIEW**
   Repeated slips or apprehension during rehabilitation warrant specialist review of stabilisation.

NOT RECOMMENDED

Sling immobilisation beyond 1 week; routine external-rotation bracing.

SEEK ASSESSMENT IF

The shoulder will not go back in, the arm is numb or weak after a slip, a fever or hot joint, or loss of rotation strength over age 40.

REFERENCES (APA 7)

Brownson, P., Donaldson, O., Fox, M., Rees, J. L., Rangan, A., Jaggi, A., Tytherleigh-Strong, G., McBernie, J., Thomas, M., & Kulkarni, R. (2015). BESS/BOA patient care pathways: Traumatic anterior shoulder instability. *Shoulder & Elbow, 7*(3), 214–226. https://doi.org/10.1177/1758573215585656

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kavaja, L., Lähdeoja, T., Malmivaara, A., & Paavola, M. (2018). Treatment after traumatic shoulder dislocation: A systematic review with a network meta-analysis. *British Journal of Sports Medicine, 52*(23), 1498–1506. https://doi.org/10.1136/bjsports-2017-098539

Olds, M., Ellis, R., Donaldson, K., Parmar, P., & Kersten, P. (2015). Risk factors which predispose first-time traumatic anterior shoulder dislocations to recurrent instability in adults: A systematic review and meta-analysis. *British Journal of Sports Medicine, 49*(14), 913–922. https://doi.org/10.1136/bjsports-2014-094342

Patrick, C. M., Snowden, J., Eckhoff, M. D., Green, C. K., Scanaliato, J. P., Dunn, J. C., & Parnes, N. (2023). Epidemiology of shoulder dislocations presenting to United States emergency departments: An updated ten-year study. *World Journal of Orthopedics, 14*(9), 690–697. https://doi.org/10.5312/wjo.v14.i9.690

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Zacchilli, M. A., & Owens, B. D. (2010). Epidemiology of shoulder dislocations presenting to emergency departments in the United States. *Journal of Bone and Joint Surgery (American Volume), 92*(3), 542–549. https://doi.org/10.2106/JBJS.I.00450

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

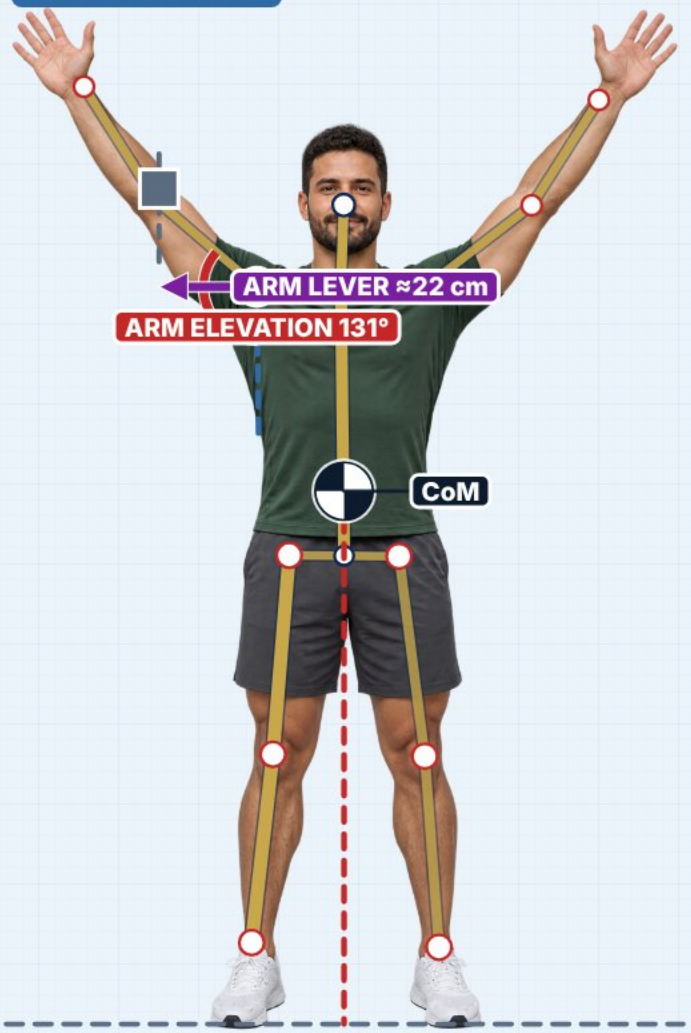
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

HYPERMOBILE SHOULDERS: BUILDING CONTROL WITHOUT FORCING RANGE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

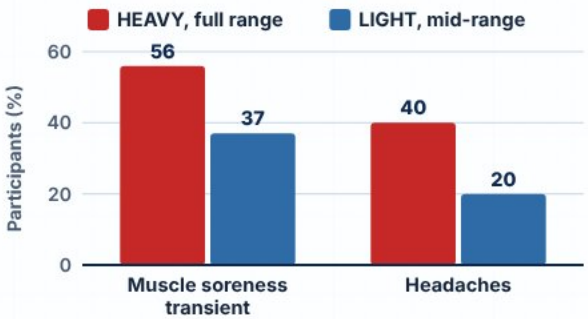
A · Y-RAISE, FRONT



Range is not the problem; control is

- Arms raised **131°** in a Y, held short of end range: the arm's weight acts **≈22 cm** from the joint, **≈7 N·m** for the cuff and deltoid to hold.
- Hypermobility means range beyond typical limits at several joints (Beighton ≥4 of 9 in adults); a symptomatic shoulder may be painful or slip in several directions (Remvig et al., 2007).

Heavier loading: more short-lived soreness



100 adults with hypermobility spectrum disorder and shoulder symptoms ≥3 months; 16 weeks. Liaghat et al. (2022).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

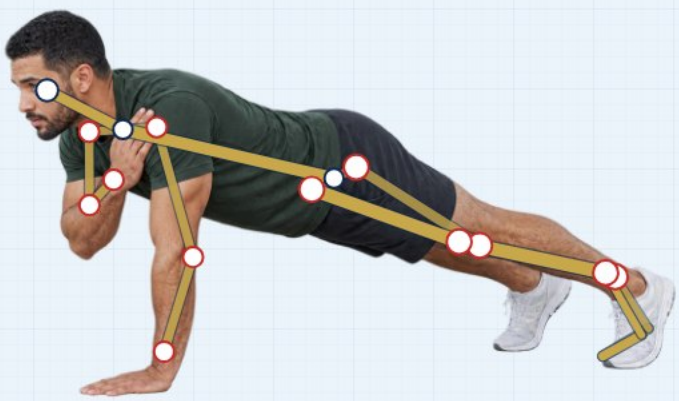
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

HYPERMOBILE SHOULDERS: BUILDING CONTROL WITHOUT FORCING RANGE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

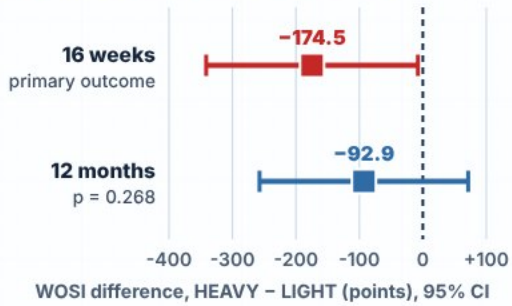
B · PLANK SHOULDER TAP, SIDE



Plank taps: control under load

- Lifting one hand in a high plank shifts body weight onto the other shoulder, which must stay centred without the arm collapsing: control is trained under load rather than at end range.
- Heavy, full-range strengthening was statistically better than light mid-range work at 16 weeks, though the mean gain was below the 252-point minimal important difference.

Heavy vs light loading (lower = better)



Western Ontario Shoulder Instability Index, 0–2,100; negative favours HEAVY. Liaghat et al. (2022, 2024).

Myth: "Loose shoulders must be protected from heavy load." Heavy loading was not harmful; extra side-effects were transient.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose angles are unreliable in plank positions. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

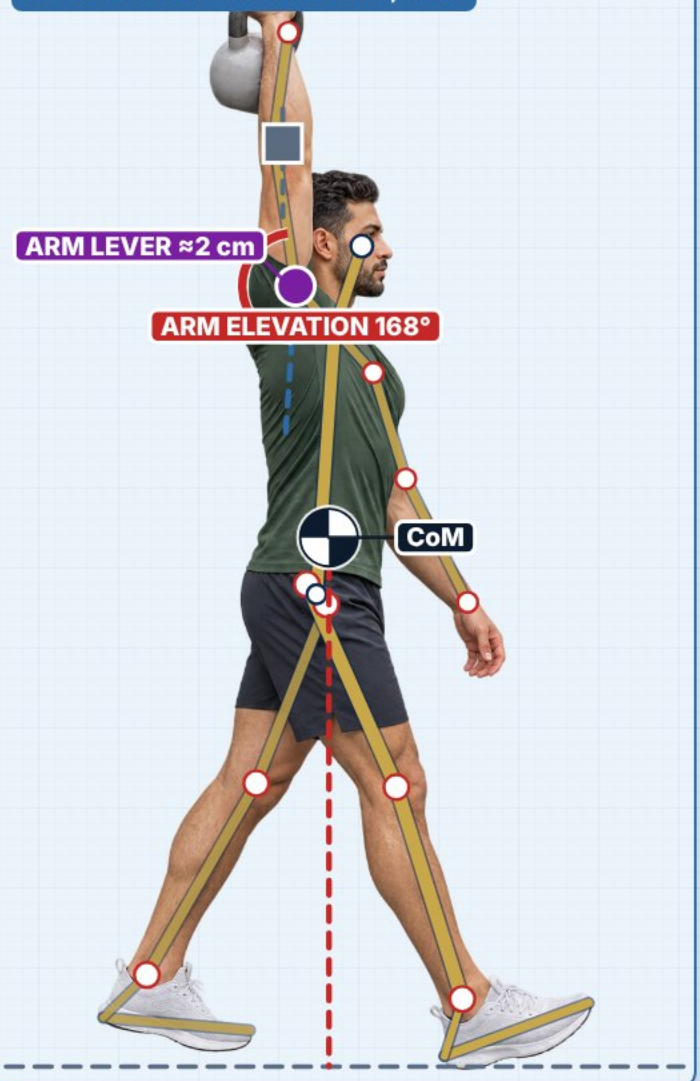
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

HYPERMOBILE SHOULDERS: BUILDING CONTROL WITHOUT FORCING RANGE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

C · OVERHEAD WAITER CARRY, SIDE



Overhead carry: stacked and steady

- Kettlebell held at **168°** while walking: the lever is only **≈2 cm**, so the task is keeping the joint centred as the body moves, not lifting.
- For multidirectional instability, a programme starting with shoulder-blade position and control, then progressing load and range, outperformed a conventional band programme.

Control-first programme for MDI



41 people with multidirectional instability, 12 weekly sessions; effects as reported in WOSI units. Warby et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

HYPERMOBILE SHOULDERS: BUILDING CONTROL WITHOUT FORCING RANGE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Y-raise
≈7 N·m

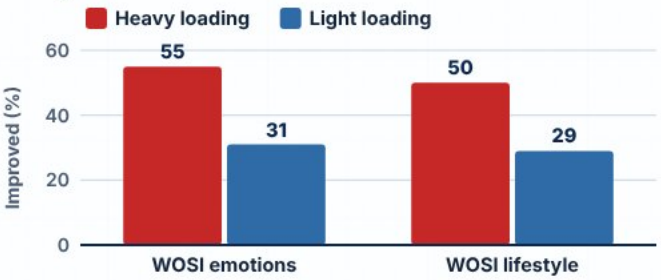


B · Plank tap
Control under load



C · Waiter carry
Lever ≈2 cm

At 1 year: confidence benefits remain



Patient-perceived effect at 12 months (p = 0.027 and 0.042); total WOSI gap no longer significant; 86 of 100 analysed. Liaghat et al. (2024).

Decision pathway

1. **CONTROL**
   Start with shoulder-blade position and joint control, then progress load and range in stages.
2. **LOAD**
   Supervised, progressive strengthening through full range is safe; expect some short-lived soreness.
3. **REVIEW**
   Judge progress on function and confidence over months, not on range gained.

NOT RECOMMENDED

Avoiding load out of fear of laxity; deliberate end-range stretching to gain more range.

SEEK ASSESSMENT IF

A first traumatic dislocation, a shoulder that will not go back in, or new numbness or weakness; widespread laxity with skin, vessel or multi-joint problems may need medical review.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Liaghat, B., Juul-Kristensen, B., Faber, D. A., Christensen, E. O., Søgaard, K., Skou, S. T., Søndergaard, J., & Juhl, C. B. (2024). One-year effectiveness of high-load compared with low-load strengthening exercise on self-reported function in patients with hypermobile shoulders: A secondary analysis from a randomised controlled trial. *British Journal of Sports Medicine, 58*(7), 373–381. https://doi.org/10.1136/bjsports-2023-107563

Liaghat, B., Skou, S. T., Søndergaard, J., Boyle, E., Søgaard, K., & Juul-Kristensen, B. (2022). Short-term effectiveness of high-load compared with low-load strengthening exercise on self-reported function in patients with hypermobile shoulders: A randomised controlled trial. *British Journal of Sports Medicine, 56*(22), 1269–1276. https://doi.org/10.1136/bjsports-2021-105223

Remvig, L., Jensen, D. V., & Ward, R. C. (2007). Epidemiology of general joint hypermobility and basis for the proposed criteria for benign joint hypermobility syndrome: Review of the literature. *The Journal of Rheumatology, 34*(4), 804–809.

Warby, S. A., Ford, J. J., Hahne, A. J., Watson, L., Balster, S., Lenssen, R., & Pizzari, T. (2018). Comparison of 2 exercise rehabilitation programs for multidirectional instability of the glenohumeral joint: A randomized controlled trial. *The American Journal of Sports Medicine, 46*(1), 87–97. https://doi.org/10.1177/0363546517734508

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

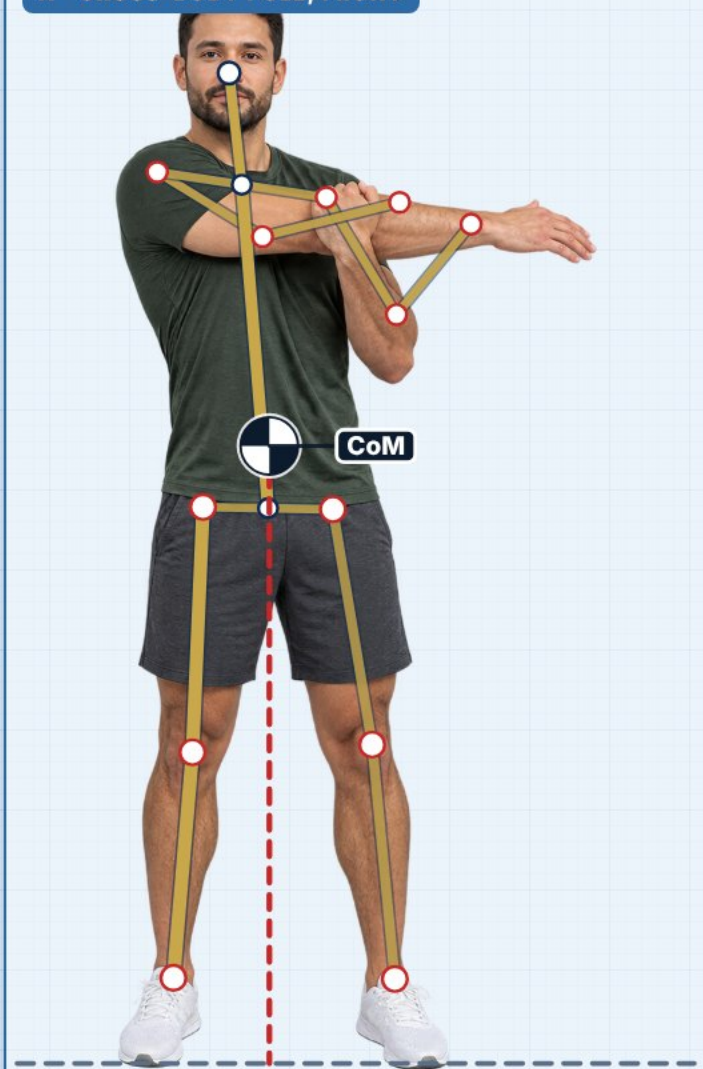
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AC JOINT PAIN: PAIN ON TOP OF THE SHOULDER

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

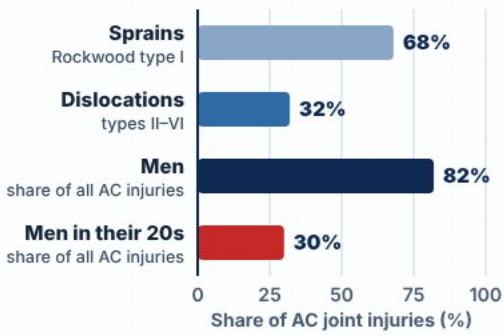
A · CROSS-BODY PULL, FRONT



Cross-body: the joint is squeezed

- Pulling the arm across the chest drives the end of the collarbone against the acromion, so this position compresses the AC joint and often reproduces pain on top of the shoulder.
- AC injuries made up 11% of all shoulder injuries in a city cohort (45 per 100,000 person-years); most were sprains in young men.

Who injures the AC joint?



287 AC injuries among 2,650 shoulder injuries, Oslo population cohort; median age 32 years. Skjaker et al. (2021).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm-crossing pose: shoulder and arm angles not measured. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AC JOINT PAIN: PAIN ON TOP OF THE SHOULDER

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

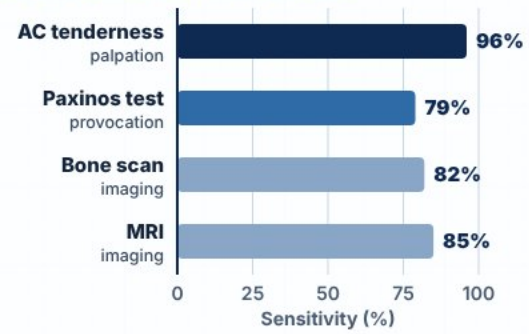
B · BENCH DIP, SIDE



Deep dips load the top of the shoulder

- Elbows bent ≈**76°** with the arms drawn behind the trunk: body weight passes through the shoulder girdle at end-range extension, a position many people with AC pain find provocative.
- Tenderness and provocation tests catch most AC pain (sensitive), but specificity was low, so a single positive test cannot confirm the joint as the source.

Tests are sensitive, not specific



38 patients; reference standard ≥50% pain relief after AC injection. Positive Paxinos + bone scan: 99% post-test probability. Walton et al. (2004).

Key point: a negative test helps rule AC pain out; a positive one needs the whole picture.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow angle from pose landmarks. Educational, not diagnostic.

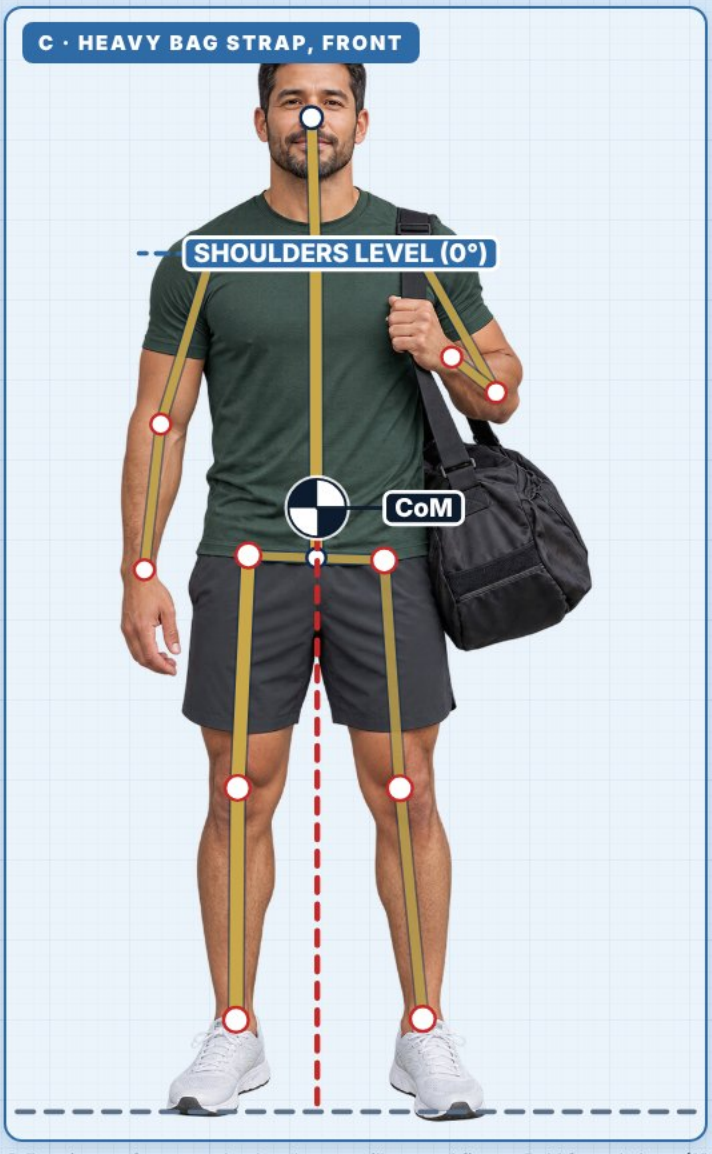
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AC JOINT PAIN: PAIN ON TOP OF THE SHOULDER

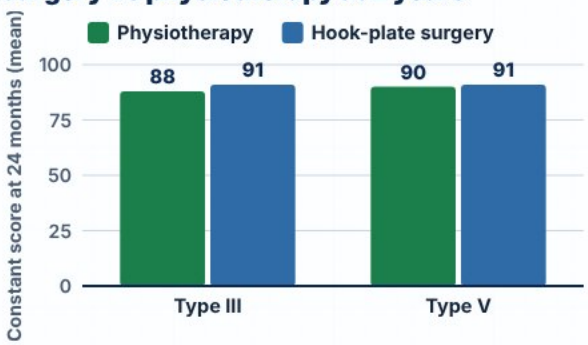
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A heavy strap sits on the joint

- Shoulders level (**0°**), yet the strap load rests directly over the AC joint and pulls the shoulder girdle down; swapping sides or using a rucksack spreads the load.
- For acute type III and V dislocations, physiotherapy gave faster early recovery than hook-plate surgery and equal function at 2 years.

Surgery vs physiotherapy at 2 years



124 adults, Rockwood type III or V, randomised; p = 0.477; 18% of the non-operative group had later surgery. Boström Windhamre et al. (2022).

Myth: "A shoulder separation with a bump needs an operation." Two-year scores were 88–91 with or without surgery.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

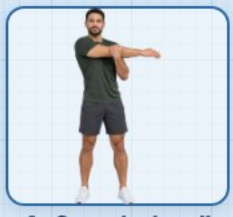
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AC JOINT PAIN: PAIN ON TOP OF THE SHOULDER

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Cross-body pull
Joint compressed

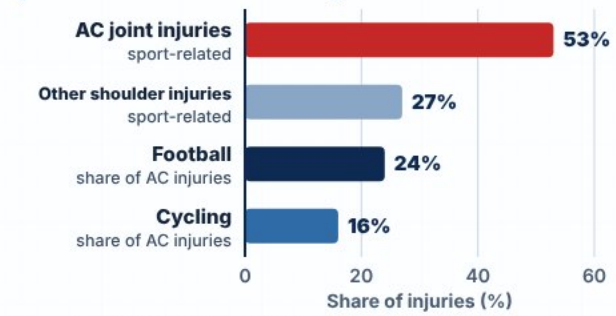


B · Bench dip
Elbow ≈76°



C · Bag strap
Load on top

Sport and falls drive AC injuries



Sport-related: OR 3.1 (95% CI 2.4–4.0) for AC vs other shoulder injuries. Skjaker et al. (2021).

Decision pathway

1. **SCREEN**
   Combine tenderness, cross-body and provocation tests with history; one positive test is not enough.
2. **MODIFY**
   Reduce compressive end-range tasks such as deep dips, cross-body pulls and heavy straps while symptoms settle.
3. **LOAD**
   Keep the shoulder strong; for acute type III and V injuries, try structured physiotherapy first.

NOT RECOMMENDED

Routine hook-plate surgery for acute type III or V injuries; diagnosing AC pain from one test.

SEEK ASSESSMENT IF

A visible step or severe pain after a fall, a suspected fracture or high-grade dislocation, numbness or weakness, or fever with a hot joint.

REFERENCES (APA 7)

Boström Windhamre, H., von Heideken, J., Une-Larsson, V., Ekström, W., & Ekelund, A. (2022). No difference in clinical outcome at 2-year follow-up in patients with type III and V acromioclavicular joint dislocation treated with hook plate or physiotherapy: A randomized controlled trial. *Journal of Shoulder and Elbow Surgery, 31*(6), 1122–1136. https://doi.org/10.1016/j.jse.2021.12.003

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Skjaker, S. A., Enger, M., Engebretsen, L., Brox, J. I., & Bøe, B. (2021). Young men in sports are at highest risk of acromioclavicular joint injuries: A prospective cohort study. *Knee Surgery, Sports Traumatology, Arthroscopy, 29*(7), 2039–2045. https://doi.org/10.1007/s00167-020-05958-x

Walton, J., Mahajan, S., Paxinos, A., Marshall, J., Bryant, C., Shnier, R., Quinn, R., & Murrell, G. A. C. (2004). Diagnostic values of tests for acromioclavicular joint pain. *Journal of Bone and Joint Surgery (American Volume), 86*(4), 807–812.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

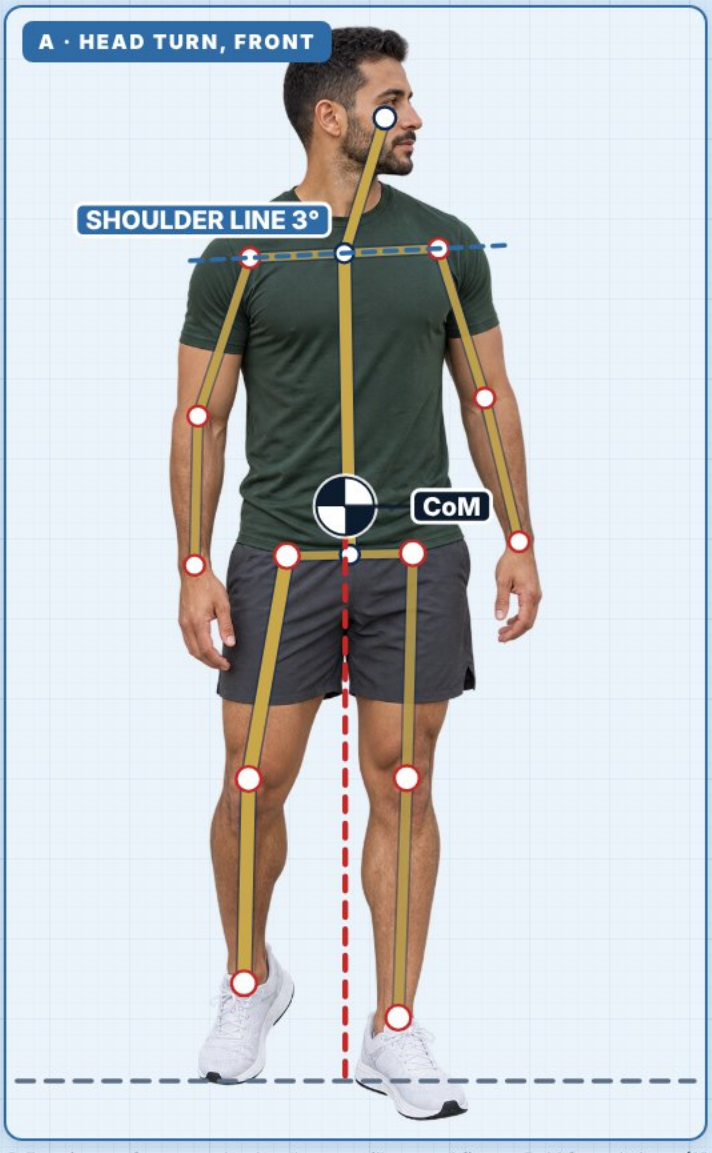
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN OR NECK PAIN? WHY THE SOURCE OF ARM PAIN MATTERS

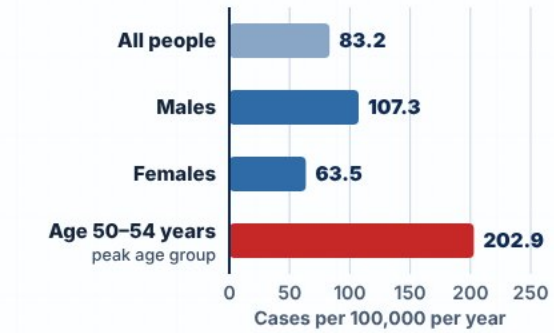
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Turning the head: a neck screen

- Looking over the shoulder, shoulder line ≈**3°**: if this reproduces arm pain, the neck rather than the shoulder may be the source.
- Cervical radiculopathy is arm pain or neurological change (numbness, weakness, reflex loss) from an irritated cervical nerve root; it can mimic shoulder pain.

Radiculopathy peaks in middle age



561 patients, Rochester, Minnesota, 1976–1990; C7 then C6 the commonest roots. Radhakrishnan et al. (1994).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

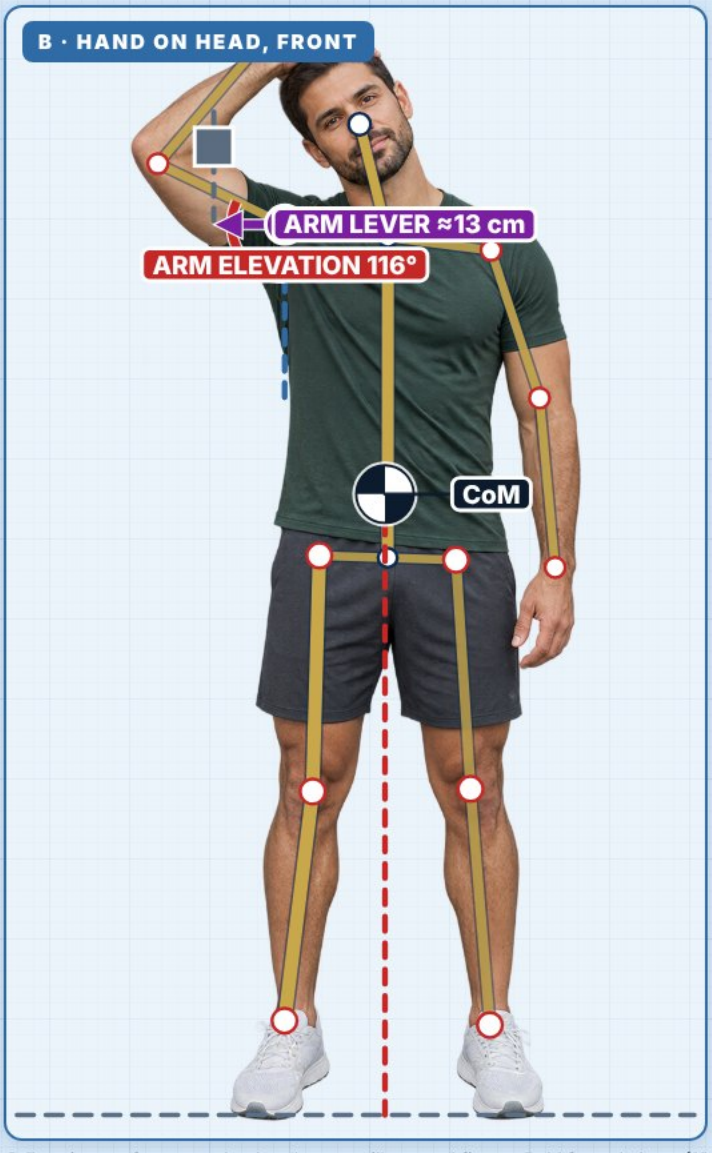
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN OR NECK PAIN? WHY THE SOURCE OF ARM PAIN MATTERS

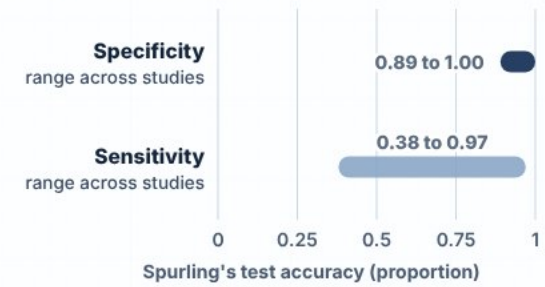
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Hand on head: watch the arm symptoms

- Hand resting on the head lifts the arm to **116°** with a lever of **≈13 cm**; note whether this position changes the arm symptoms.
- Spurling's test (extension, side-bend and rotation with compression) is specific but variably sensitive: a positive test raises suspicion, a negative test does not rule radiculopathy out.

Spurling's: good for ruling in



Systematic review of five diagnostic-accuracy studies; use clusters of history, neurological examination and tests. Thoomes et al. (2018).

Myth: "Pain felt in the shoulder comes from the shoulder." Most radiculopathy starts without trauma (only 14.8% after exertion or injury).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

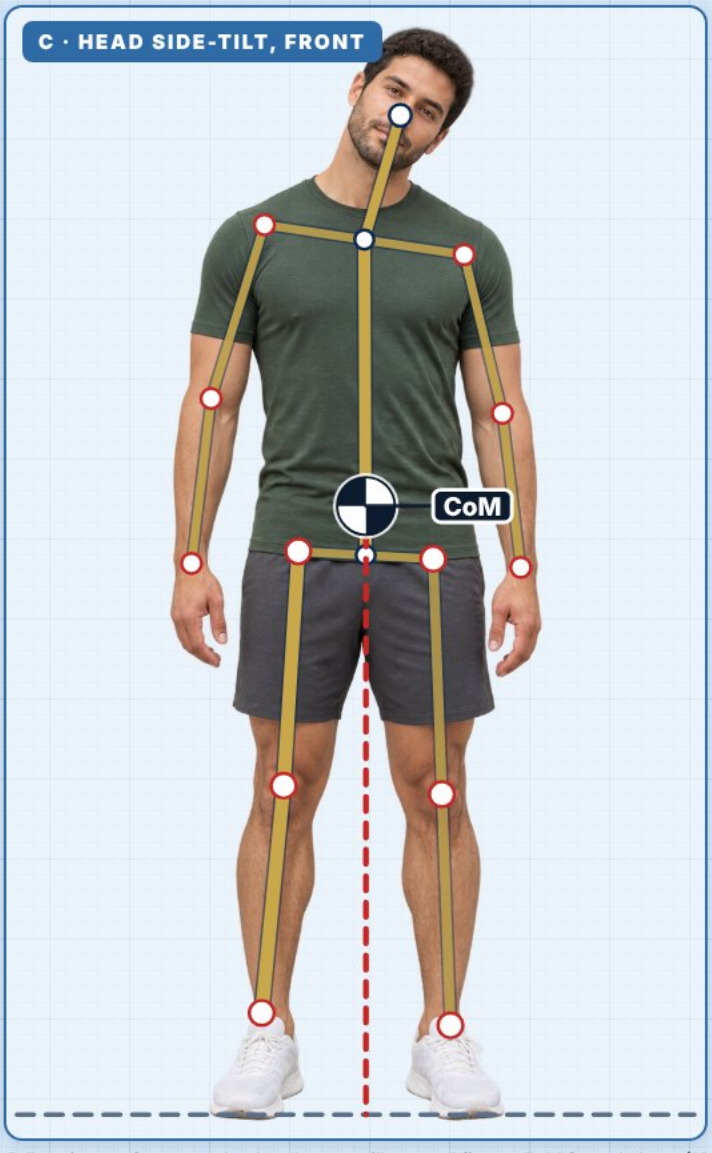
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN OR NECK PAIN? WHY THE SOURCE OF ARM PAIN MATTERS

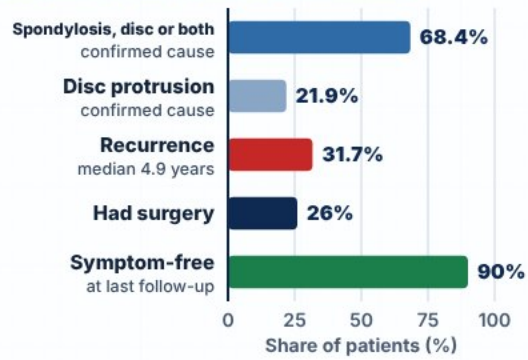
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Side-tilt: part of the neck picture

- Side-bending the head is one component of Spurling's test; arm symptoms that change with neck movement, or spread below the elbow, point towards the neck rather than the shoulder.
- Most people recover, but about a third have a recurrence, so explain the course honestly and check the neck whenever arm symptoms come and go.

Cause and course in the community



Same Rochester cohort; median symptom duration before diagnosis 15 days. Radhakrishnan et al. (1994).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Head-tilt pose: neck angle not measured from 2-D landmarks. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

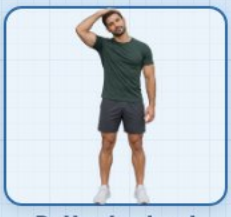
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN OR NECK PAIN? WHY THE SOURCE OF ARM PAIN MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Head turn
Neck screen

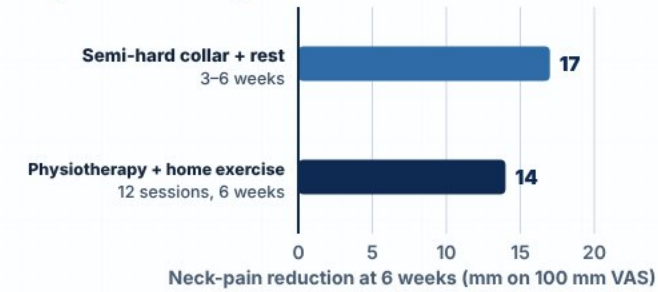


B · Hand on head
116° elevation



C · Side-tilt
Spurling component

Early active care speeds relief



205 patients, symptoms <1 month; neck-pain change with wait-and-see not significant; both active options gave 12 mm extra arm-pain relief. Kuijper et al. (2009).

Decision pathway

1. **SCREEN**
   If pain spreads below the elbow, or with numbness or weakness, examine the neck and nerves.
2. **CLUSTER**
   Combine history, neurological signs and tests; a negative Spurling's does not exclude the neck.
3. **TREAT**
   Explain the usually favourable course; active physiotherapy with home exercise speeds early relief.

NOT RECOMMENDED

Treating the shoulder alone when neurological signs point to the neck.

SEEK ASSESSMENT IF

Progressive weakness, symptoms in both arms or legs, clumsy hands or unsteady walking, weight loss, cancer history, fever, or chest pain with breathlessness.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kuijper, B., Tans, J. T. J., Beelen, A., Nollet, F., & de Visser, M. (2009). Cervical collar or physiotherapy versus wait and see policy for recent onset cervical radiculopathy: Randomised trial. *BMJ, 339*, b3883. https://doi.org/10.1136/bmj.b3883

Radhakrishnan, K., Litchy, W. J., O'Fallon, W. M., & Kurland, L. T. (1994). Epidemiology of cervical radiculopathy: A population-based study from Rochester, Minnesota, 1976 through 1990. *Brain, 117*(2), 325–335.

Thoomes, E. J., van Geest, S., van der Windt, D. A., Falla, D., Verhagen, A. P., Koes, B. W., Thoomes-de Graaf, M., Kuijper, B., Scholten-Peeters, W. G. M., & Vleggeert-Lankamp, C. L. (2018). Value of physical tests in diagnosing cervical radiculopathy: A systematic review. *The Spine Journal, 18*(1), 179–189. https://doi.org/10.1016/j.spinee.2017.08.241

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

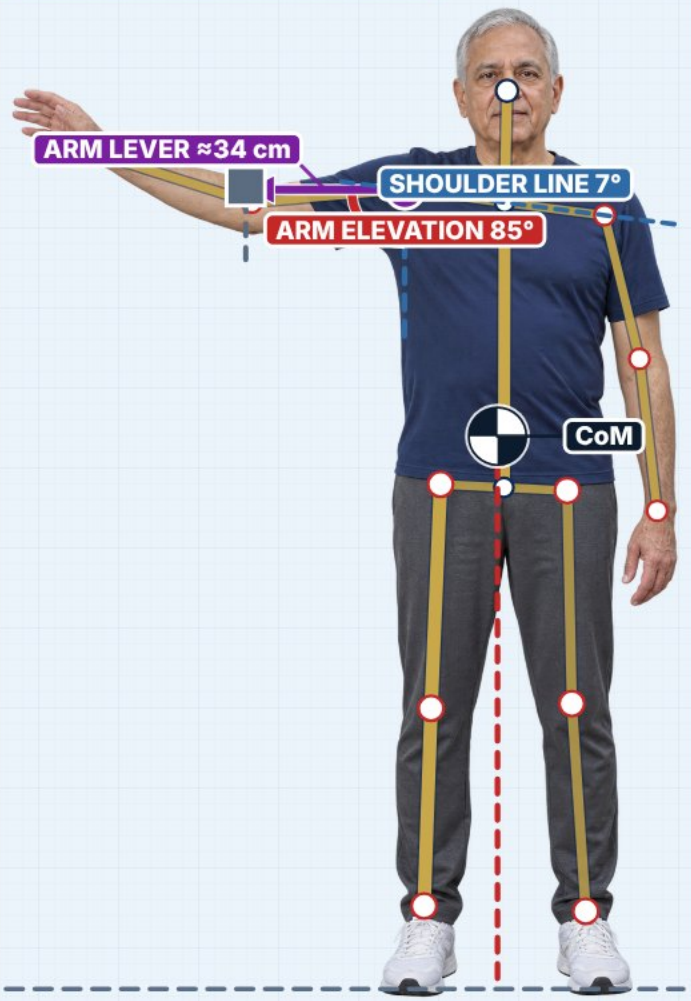
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WEAKNESS LIFTING THE ARM: WHEN TO SUSPECT A LARGE CUFF TEAR

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

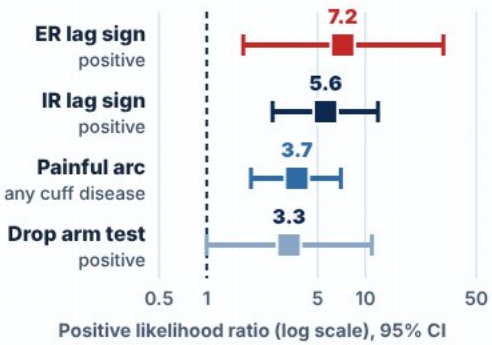
A · SIDE RAISE ATTEMPT, FRONT



Lifting with a shrug

- Arm at **85°** to the trunk with the shoulder line tilted **7°**: hitching the shoulder girdle can substitute for weak cuff elevation, while the arm's lever (≈**34 cm**) asks for ≈**11 N·m**.
- Inability to hold the arm in rotation (a lag sign) was more informative for a full-thickness tear than pain on lifting.

Which signs raise the probability?



Full-thickness tear unless stated; 28 studies of referred patients, few high quality. A normal IR lag test: LR 0.04. Hermans et al. (2013).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Shoulder line from left and right shoulder points. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WEAKNESS LIFTING THE ARM: WHEN TO SUSPECT A LARGE CUFF TEAR

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

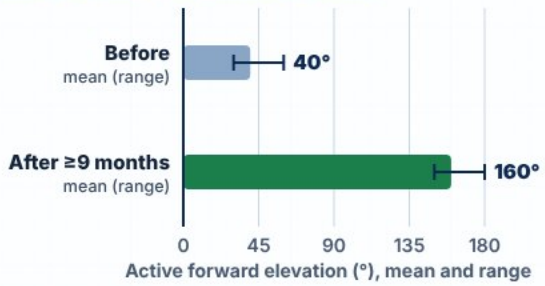
B · SUPINE ARM RAISE, SIDE



Lying down takes gravity out

- Raising the straight arm towards the ceiling while lying supine is the start of anterior deltoid re-education; the arm balances over the joint, so a weak shoulder can control it.
- The programme progresses by inclining the trunk, adding gravity in stages, and can restore elevation in some people even when the cuff cannot be repaired.

Deltoid training for massive tears



17 medically unfit adults, mean age 80, massive irreparable tears; case series without a control group. Levy et al. (2008).

Myth: "If you can't lift your arm, nothing can be done." Elevation improved from a mean 40° to 160° in this series.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose angles are unreliable in this lying position. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

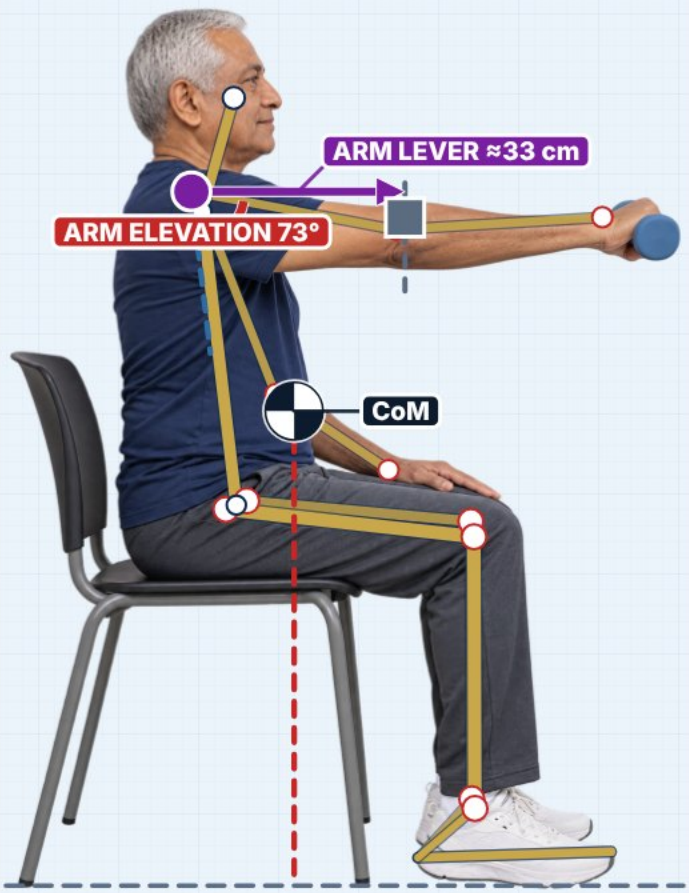
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WEAKNESS LIFTING THE ARM: WHEN TO SUSPECT A LARGE CUFF TEAR

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

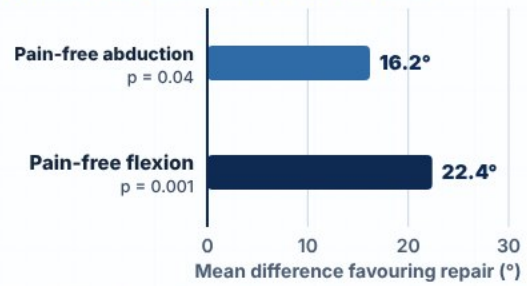
C · SEATED FRONT RAISE, SIDE



Forward raise: a long lever

- Arm at **73°**: the hand sits ≈**63 cm** in front of the joint, so even a 1 kg dumbbell brings the moment to ≈**17 N·m**, enough to expose a weak cuff.
- In small-to-medium tears left to physiotherapy, mean tear size rose from 16.2 to 31.6 mm over 15 years; early repair kept a modest advantage.

Repair vs physiotherapy at 15 years



103 randomised, tears ≤3 cm; 83 seen at 15 years; Constant +11.8 and ASES +13.9 points for repair. Moosmayer et al. (2024).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Hand load 1 kg assumed. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

WEAKNESS LIFTING THE ARM: WHEN TO SUSPECT A LARGE CUFF TEAR

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Side raise
Shrug, 85°

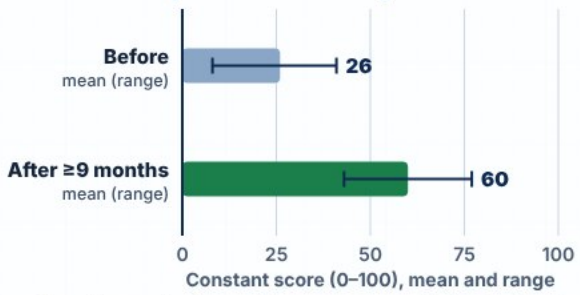


B · Supine raise
Gravity reduced



C · Front raise
≈17 N·m with 1 kg

Function can improve without repair



Older adults with massive irreparable tears; uncontrolled series, low-level evidence. Levy et al. (2008).

Decision pathway

1. **TEST**
   Check strength and lag signs; a positive lag sign makes a full-thickness tear more likely than pain alone.
2. **REFER**
   Suspected full-thickness tear: imaging and specialist review; repairable tears may do better with repair.
3. **RETRAIN**
   If repair is not an option, graded deltoid training from lying to upright can restore elevation.

NOT RECOMMENDED

Ruling a tear in or out on one test or on pain alone; assuming a tear will not enlarge.

SEEK ASSESSMENT IF

Sudden loss of lifting or rotation after a fall or dislocation, especially over 40; or weakness with neck pain, pins and needles or reflex change.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hermans, J., Luime, J. J., Meuffels, D. E., Reijman, M., Simel, D. L., & Bierma-Zeinstra, S. M. (2013). Does this patient with shoulder pain have rotator cuff disease? The Rational Clinical Examination systematic review. *JAMA, 310*(8), 837–847. https://doi.org/10.1001/jama.2013.276187

Levy, O., Mullett, H., Roberts, S., & Copeland, S. (2008). The role of anterior deltoid reeducation in patients with massive irreparable degenerative rotator cuff tears. *Journal of Shoulder and Elbow Surgery, 17*(6), 863–870.

Moosmayer, S., Lund, G., Seljom, U. S., Haldorsen, B., Svege, I. C., Hennig, T., Pripp, A. H., & Smith, H.-J. (2024). Fifteen-year results of a comparative analysis of tendon repair versus physiotherapy for small-to-medium-sized rotator cuff tears: A concise follow-up of previous reports. *Journal of Bone and Joint Surgery (American Volume), 106*(19), 1785–1796. https://doi.org/10.2106/JBJS.24.00065

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

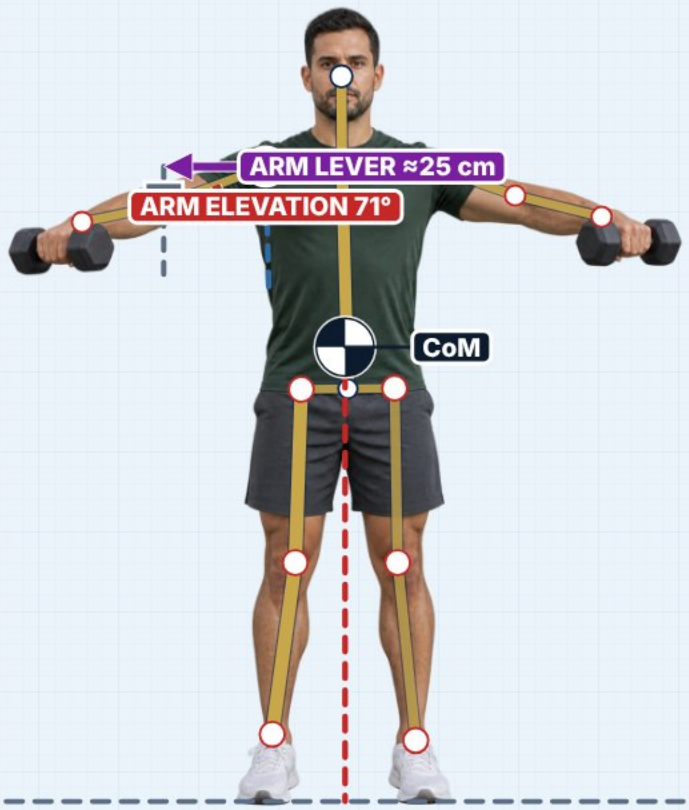
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INJECTION OR EXERCISE: WHAT THE EVIDENCE SHOWS OVER TIME

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

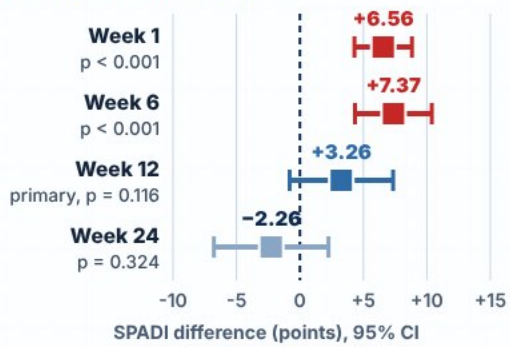
A · LATERAL RAISE, FRONT



Light lateral raise: a graded lever

- Arms at **71°**: with a 1 kg dumbbell the hand sits **≈44 cm** out from the joint, giving **≈13 N·m** per shoulder; height and weight set the dose.
- Adding an injection before exercise gave a clear advantage in the first 6 weeks; by 12 and 24 weeks the gap had closed.

The injection advantage fades



232 adults ≥40 years, subacromial pain; positive favours injection + exercise (n = 115) over exercise alone (n = 117). Crawshaw et al. (2010).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Hand load 1 kg assumed. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

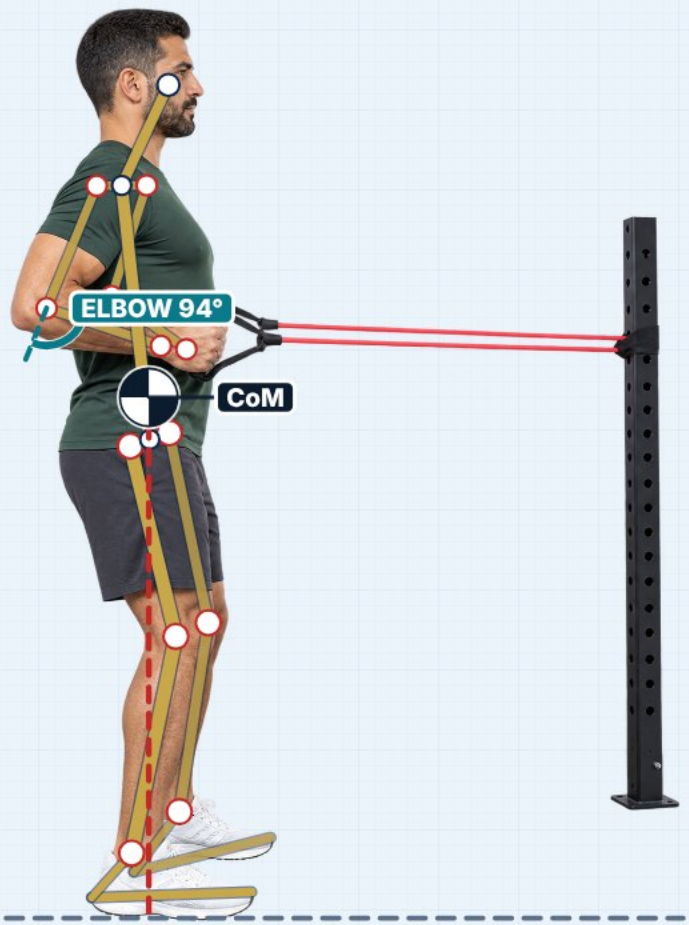
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INJECTION OR EXERCISE: WHAT THE EVIDENCE SHOWS OVER TIME

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

B · BAND ROW, SIDE



Band row: shoulder-blade work

- Elbows drawn back to ≈**94°** of flexion against a band: the shoulder blade retracts and the posterior cuff works, with resistance easy to grade.
- In the largest primary-care trial, injection gave a small benefit at 8 weeks that was no longer present at 12 months.

GRASP: short-term relief only



708 adults, 20 NHS services; SPADI 0–100, lower = better; negative favours injection. Hopewell et al. (2021).

Myth: "The injection fixes the shoulder; exercise is optional." Its advantage was gone by 12–24 weeks in both trials.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow angle from pose landmarks. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

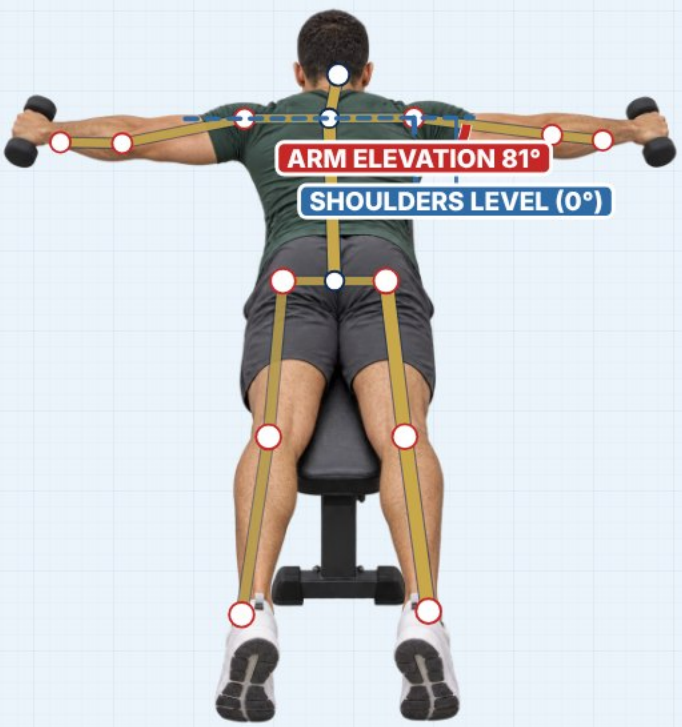
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INJECTION OR EXERCISE: WHAT THE EVIDENCE SHOWS OVER TIME

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

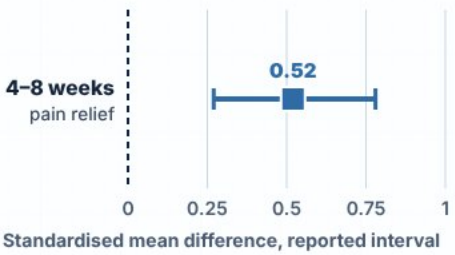
C · PRONE T-RAISE, REAR



Prone T: rear shoulder endurance

- Chest supported on the bench, arms out at **81°** to the trunk: very light dumbbells challenge the rear deltoid and shoulder-blade muscles against gravity.
- Across 11 trials, injection reduced pain at 4–8 weeks but not at 3 months; at least five people must be treated for one to gain transient relief.

A small, transient effect



11 RCTs, 726 adults with rotator cuff tendinosis; no reduction at 3 months; repeat injections studied in only 3 trials. Mohamadi et al. (2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Rear view: arm angle to the trunk line and shoulder line from pose landmarks. Educational, not diagnostic.

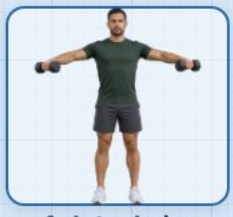
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER INJECTION OR EXERCISE: WHAT THE EVIDENCE SHOWS OVER TIME

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Lateral raise
≈13 N·m with 1 kg

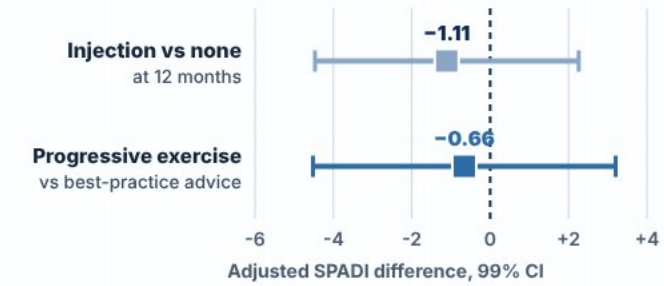


B · Band row
Elbow ≈94°



C · Prone T
Light, rear shoulder

At 12 months: no clear difference



GRASP factorial trial, 708 adults; a session of advice plus home exercise did as well as a longer supervised programme. Hopewell et al. (2021).

Decision pathway

1. **EXERCISE**
   Make progressive loading the long-term foundation, using light raises, rows and prone work.
2. **OPTION**
   Consider an injection only to enable exercise when pain blocks it; expect relief for weeks, not months.
3. **DOSE**
   Good advice and a home programme can be enough; review progress at about 3 months.

NOT RECOMMENDED

Expecting an injection to give lasting relief; routine repeated injections.

SEEK ASSESSMENT IF

Fever, a hot swollen joint or rapidly worsening pain after an injection; night pain with weight loss or cancer history; new arm weakness.

REFERENCES (APA 7)

Crawshaw, D. P., Helliwell, P. S., Hensor, E. M. A., Hay, E. M., Aldous, S. J., & Conaghan, P. G. (2010). Exercise therapy after corticosteroid injection for moderate to severe shoulder pain: Large pragmatic randomised trial. *BMJ, 340*, c3037. https://doi.org/10.1136/bmj.c3037

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hopewell, S., Keene, D. J., Heine, P., Marian, I. R., Dritsaki, M., Cureton, L., Dutton, S. J., Dakin, H., Carr, A., Hamilton, W., Hansen, Z., Jaggi, A., Littlewood, C., Barker, K., Gray, A., & Lamb, S. E. (2021). Progressive exercise compared with best-practice advice, with or without corticosteroid injection, for rotator cuff disorders: The GRASP factorial RCT. *Health Technology Assessment, 25*(48), vii–90. https://doi.org/10.3310/hta25480

Mohamadi, A., Chan, J. J., Claessen, F. M., Ring, D., & Chen, N. C. (2017). Corticosteroid injections give small and transient pain relief in rotator cuff tendinosis: A meta-analysis. *Clinical Orthopaedics and Related Research, 475*(1), 232–243. https://doi.org/10.1007/s11999-016-5002-1

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

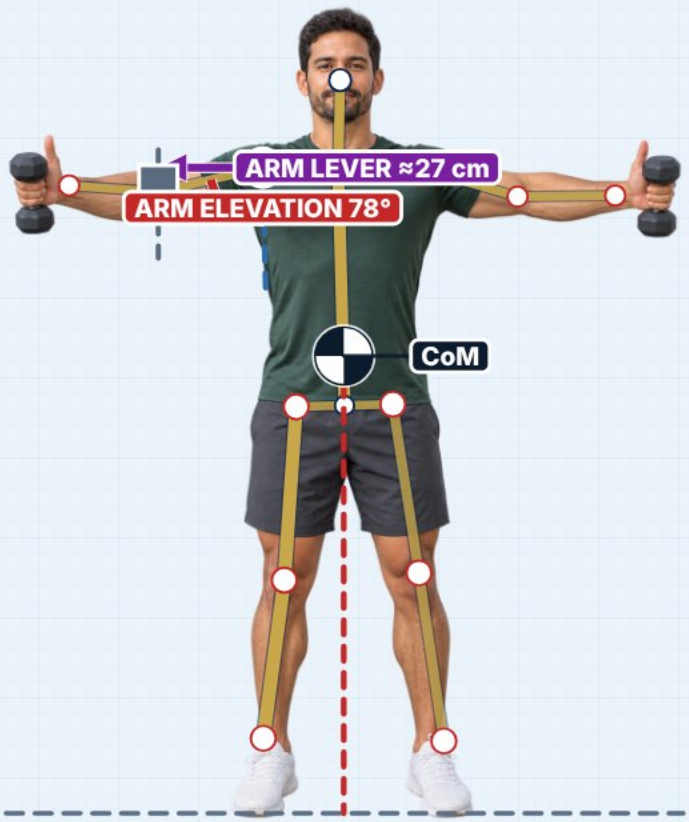
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL DECOMPRESSION SURGERY: WHAT THE CSAW AND FIMPACT TRIALS FOUND

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

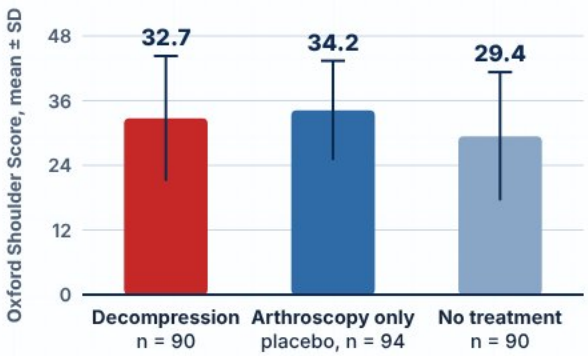
A · SCAPTION RAISE, FRONT



The impingement model, tested

- Raising the arms to **78°** in the scapular plane: with a 1 kg dumbbell the hand sits **≈51 cm** from the joint, **≈14 N·m**, a gradable cuff load.
- Decompression shaves the under-surface of the acromion to "make space"; CSAW compared it with placebo surgery (arthroscopy only) and with no treatment.

CSAW at 6 months (higher = better)



Score 0–48; decompression vs arthroscopy −1.3 (95% CI −3.9 to 1.3), p = 0.31. Beard et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Hand load 1 kg assumed. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

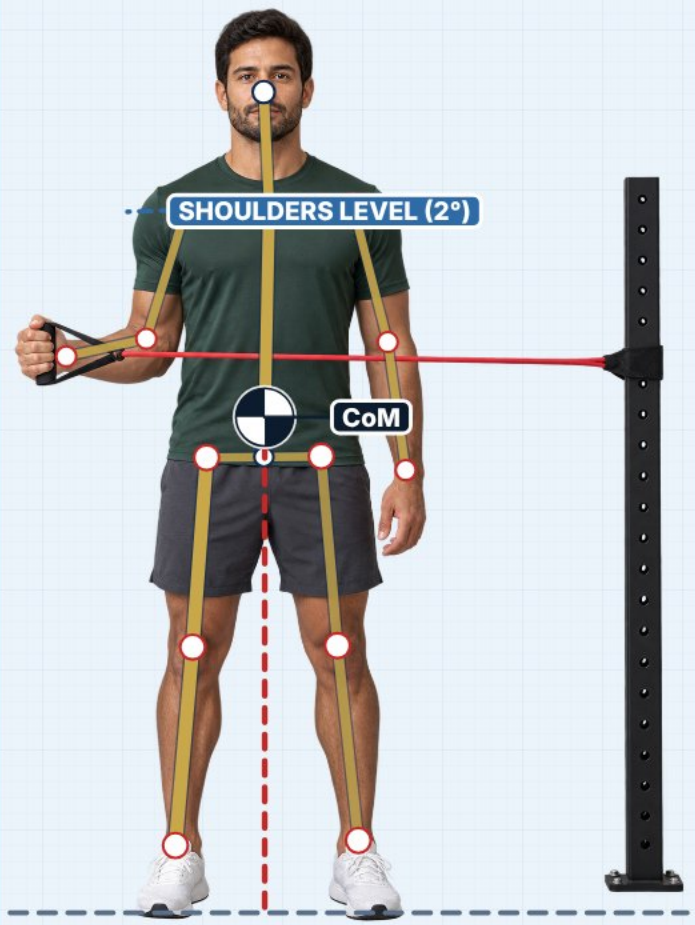
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL DECOMPRESSION SURGERY: WHAT THE CSAW AND FIMPACT TRIALS FOUND

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

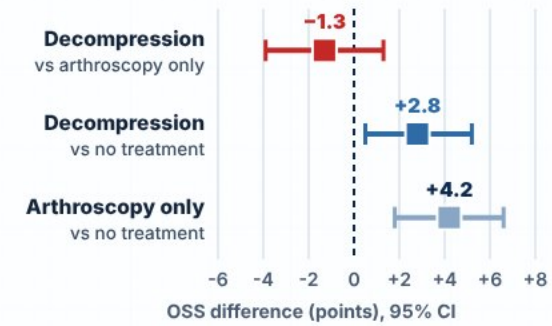
B · BAND EXTERNAL ROT., FRONT



Band rotation: cuff work without surgery

- Elbow held at the side, forearm rotating out against a band shoulders level (**2°**): a low-load exercise for the posterior cuff that is easy to progress.
- Removing bone added nothing over placebo surgery; both surgical groups only slightly beat no treatment, and the authors judged those gaps not clinically important.

CSAW: differences between groups



Positive favours the first-named group; the trial was designed to detect 4.5 points. Beard et al. (2018).

Myth: "Shaving the bone stops the tendon being pinched, so surgery is the fix." Placebo-controlled trials did not support this.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

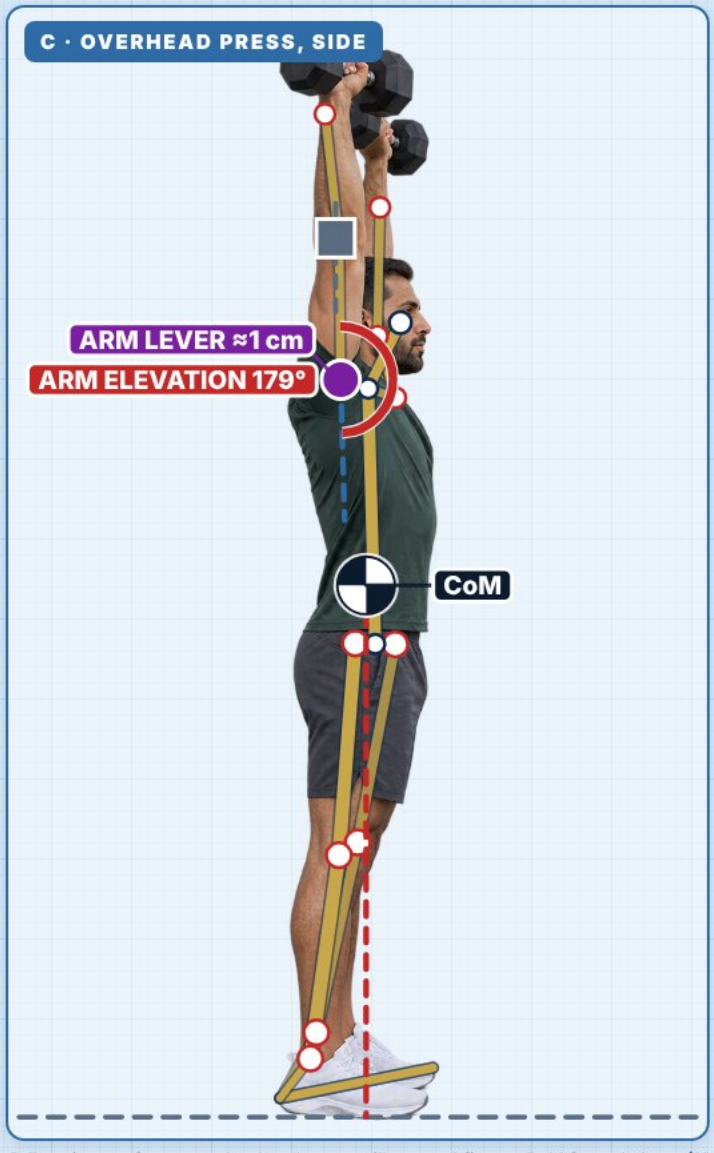
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL DECOMPRESSION SURGERY: WHAT THE CSAW AND FIMPACT TRIALS FOUND

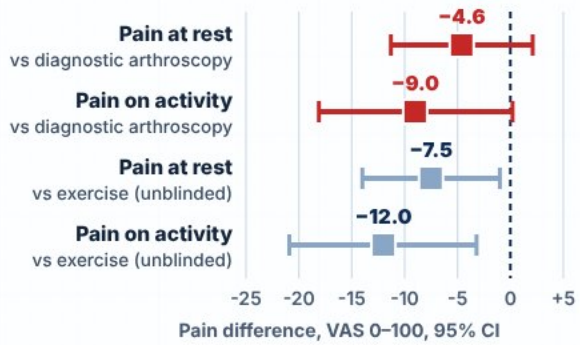
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Overhead press: an end-stage goal

- Arms locked out at **179°**: the weight sits almost over the joint (lever ≈**1 cm**), so the demand is control at end range, a late target in rehabilitation.
- In FIMPACT no difference reached the 15-point minimal important difference; the contrast with exercise was unblinded and, per the authors, biased towards surgery.

FIMPACT at 24 months



210 patients, Finland; negative favours decompression; MCID 15 points. Paavola et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SUBACROMIAL DECOMPRESSION SURGERY: WHAT THE CSAW AND FIMPACT TRIALS FOUND

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Scaption raise
≈14 N·m with 1 kg

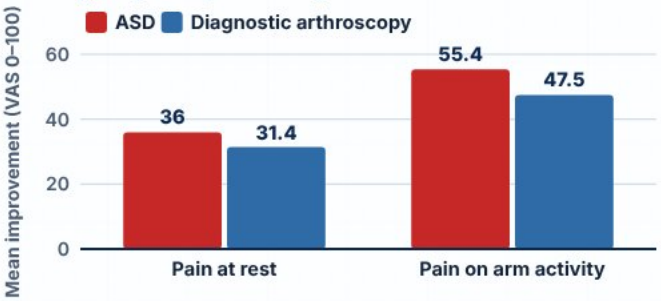


B · Band rotation
Low-load cuff work



C · Overhead press
End-stage goal

Both groups improved by similar amounts



FIMPACT blinded comparison, 24 months; ASD = decompression; between-group gaps 4.6 and 9.0 points, below the MCID. Paavola et al. (2018).

Decision pathway

1. **EXPLAIN**
   Share that placebo-controlled trials found no added benefit from removing bone.
2. **LOAD**
   Use progressive cuff and shoulder loading as first-line care, from scapular-plane raises to overhead work.
3. **DECIDE**
   A guideline panel strongly recommends against decompression for atraumatic pain over 3 months (Vandvik et al., 2019).

NOT RECOMMENDED

Subacromial decompression for atraumatic subacromial pain lasting more than 3 months.

SEEK ASSESSMENT IF

Pain after significant trauma with new weakness, suspected full-thickness tear in a younger active person, locking or instability, or fever, weight loss or night pain.

REFERENCES (APA 7)

Beard, D. J., Rees, J. L., Cook, J. A., Rombach, I., Cooper, C., Merritt, N., Shirkey, B. A., Donovan, J. L., Gwilym, S., Savulescu, J., Moser, J., Gray, A., Jepson, M., Tracey, I., Judge, A., Wartolowska, K., Carr, A. J., Ahrens, P., Baldwick, C., Brinsden, M., ... CSAW Study Group. (2018). Arthroscopic subacromial decompression for subacromial shoulder pain (CSAW): A multicentre, pragmatic, parallel group, placebo-controlled, three-group, randomised surgical trial. *The Lancet, 391*(10118), 329–338. https://doi.org/10.1016/S0140-6736(17)32457-1

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Paavola, M., Malmivaara, A., Taimela, S., Kanto, K., Inkinen, J., Kalske, J., Sinisaari, I., Savolainen, V., Ranstam, J., Järvinen, T. L. N., & FIMPACT Investigators. (2018). Subacromial decompression versus diagnostic arthroscopy for shoulder impingement: Randomised, placebo surgery controlled clinical trial. *BMJ, 362*, k2860. https://doi.org/10.1136/bmj.k2860

Vandvik, P. O., Lähdeoja, T., Ardern, C., Buchbinder, R., Moro, J., Brox, J. I., Burgers, J., Hao, Q. K., Karjalainen, T., van den Bekerom, M., Noorduyn, J., Lytvyn, L., Siemieniuk, R. A. C., Albin, A., Shunjie, S. C., Fisch, F., Proulx, L., Guyatt, G., Agoritsas, T., & Poolman, R. W. (2019). Subacromial decompression surgery for adults with shoulder pain: A clinical practice guideline. *BMJ, 364*, l294. https://doi.org/10.1136/bmj.l294

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

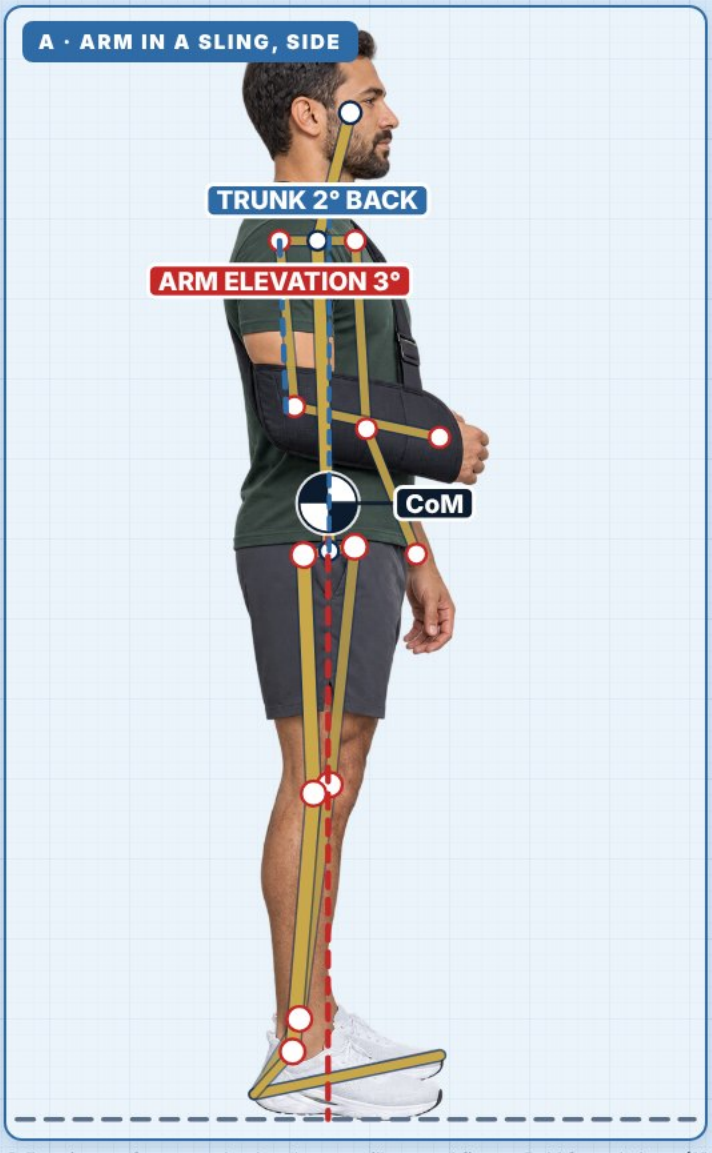
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER ROTATOR CUFF REPAIR: WHY EARLY LOADING MUST BE GRADED

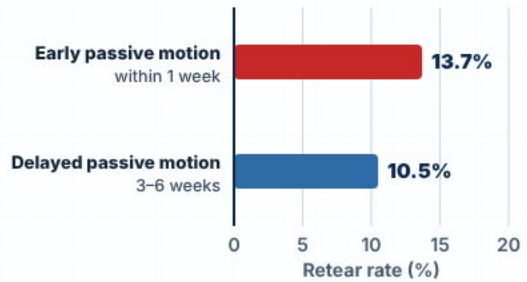
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



The sling protects, but also stiffens

- Arm supported at the side (**3°** elevation), trunk upright (**2°**): the repair is unloaded, but weeks of immobility trade protection against stiffness.
- Across level 1 studies, starting gentle passive motion within the first week did not clearly change the overall retear rate compared with waiting 3–6 weeks.

Early vs delayed motion: retear



28 studies, 1,729 repairs; RR 1.30 (95% CI 0.74–2.30), p = 0.36. Kluczynski et al. (2015).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and trunk angle from pose landmarks in the side view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

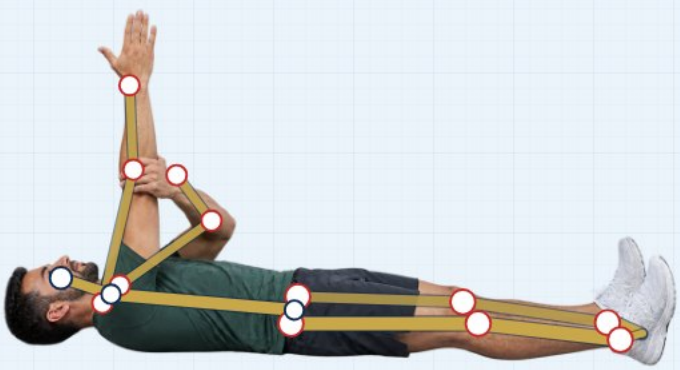
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER ROTATOR CUFF REPAIR: WHY EARLY LOADING MUST BE GRADED

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

B · ASSISTED ARM RAISE, SIDE



Assisted raise: the other arm does the work

- Lying supine and lifting the operated arm with the other hand is an early passive-to-assisted stage: the repaired tendon moves while the healthy arm carries the load.
- Tear size changed the answer: early motion was linked with fewer retears after small repairs but more than double the risk after repairs of 5 cm or more.

Tear size changes the risk



Below 1 favours early motion; pooled trial and observational data (association). Kluczynski et al. (2015).

Key point: timing must follow tear size and the surgeon's protocol, not one calendar for everyone.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose angles are unreliable in this lying position. Educational, not diagnostic.

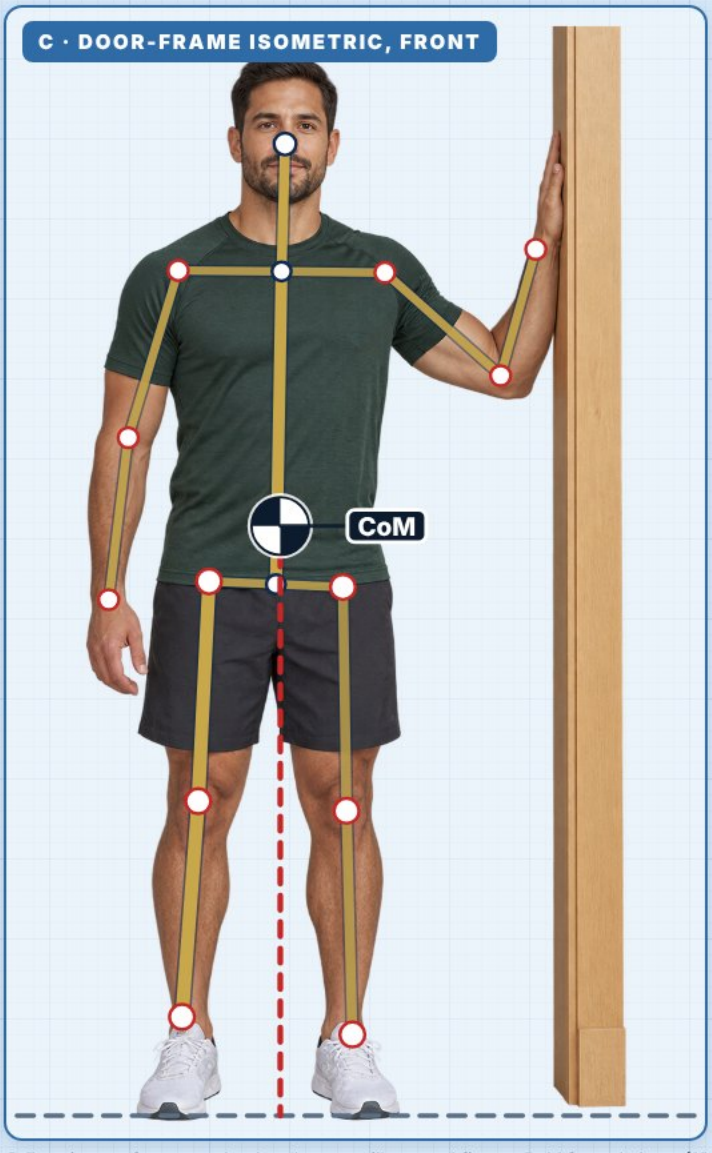
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER ROTATOR CUFF REPAIR: WHY EARLY LOADING MUST BE GRADED

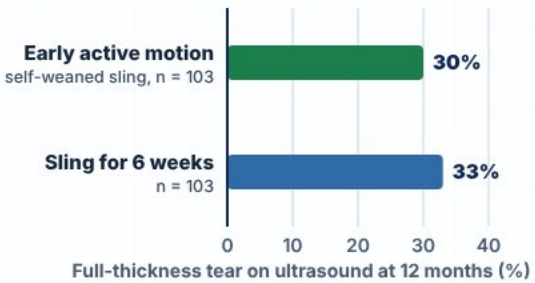
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Isometrics: load without movement

- Pressing the hand into a door frame makes the shoulder muscles contract while the joint stays still, a low-load way to start strengthening once the surgeon allows.
- Pain-free active motion in the first 6 weeks gave better flexion and abduction at 6 weeks, with no group differences later and similar repair integrity at 12 months ($p > 0.8$).

Early active motion vs sling



206 patients, arthroscopic repair of full-thickness tears; mean age 55.9 years. Sheps et al. (2019).

Myth: "The longer the arm stays in the sling, the safer the repair." Not for typical repairs in this trial.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Isometric pose: angles not quoted. Educational, not diagnostic.

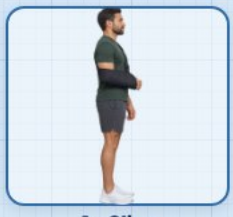
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER ROTATOR CUFF REPAIR: WHY EARLY LOADING MUST BE GRADED

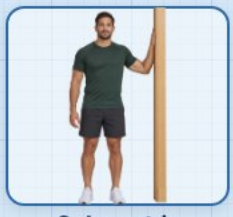
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Sling
3° elevation

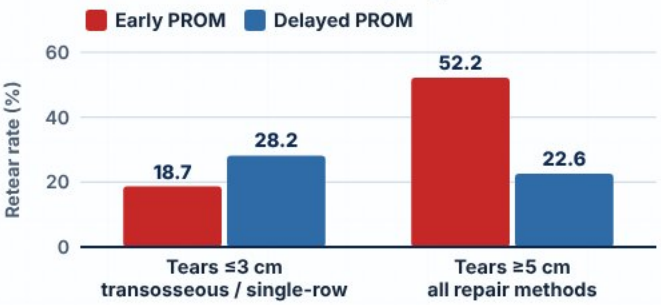


B · Assisted raise
Healthy arm lifts



C · Isometric
Load, no movement

One timeline does not fit every repair



PROM = passive range of motion; early within 1 week, delayed 3–6 weeks. Kluczynski et al. (2015).

Decision pathway

1. **PROTECT**
   Follow the surgeon's protocol, graded to tear size and repair quality.
2. **MOVE**
   For typical repairs, pain-free active motion in the first 6 weeks can be considered; be cautious after large repairs.
3. **LOAD**
   Progress from assisted motion to isometrics, then to graded resisted work.

NOT RECOMMENDED

The same timeline for every repair; aggressive early resisted loading.

SEEK ASSESSMENT IF

Fever, wound redness or discharge, rapidly rising pain, a sudden pop with new loss of lifting, or calf swelling, chest pain or breathlessness.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kluczynski, M. A., Nayyar, S., Marzo, J. M., & Bisson, L. J. (2015). Early versus delayed passive range of motion after rotator cuff repair: A systematic review and meta-analysis. *The American Journal of Sports Medicine, 43*(8), 2057–2063. https://doi.org/10.1177/0363546514552802

Sheps, D. M., Silveira, A., Beaupre, L., Styles-Tripp, F., Balyk, R., Lalani, A., Glasgow, R., Bergman, J., Bouliane, M., & Shoulder and Upper Extremity Research Group of Edmonton (SURGE). (2019). Early active motion versus sling immobilization after arthroscopic rotator cuff repair: A randomized controlled trial. *Arthroscopy, 35*(3), 749–760. https://doi.org/10.1016/j.arthro.2018.10.139

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

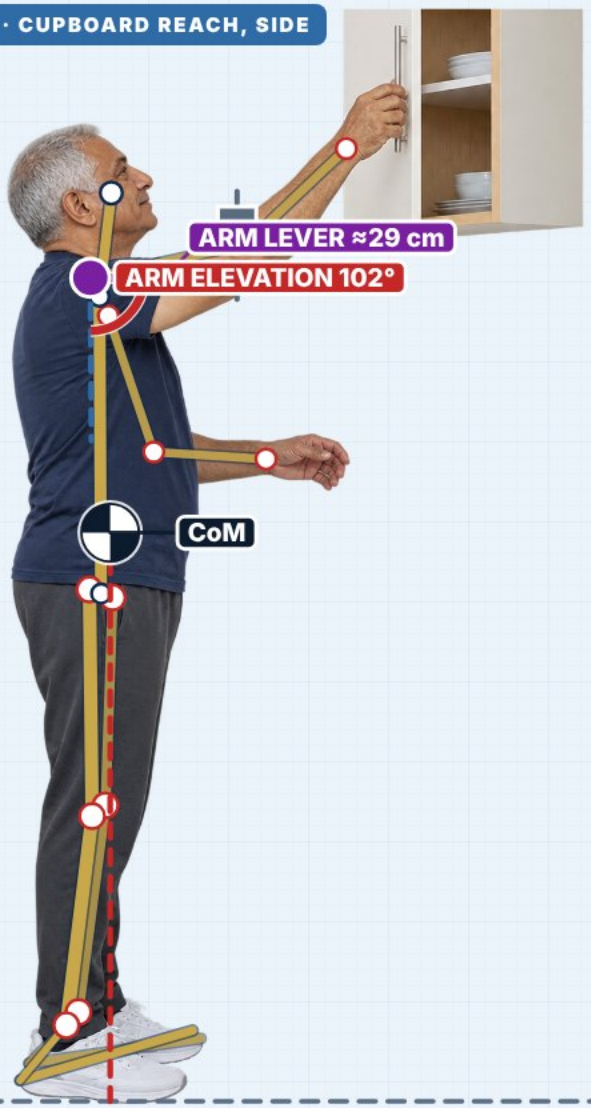
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER SHOULDER REPLACEMENT: REGAINING REACH, STRENGTH AND DAILY FUNCTION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

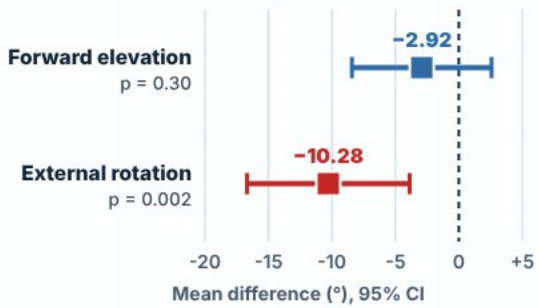
A · CUPBOARD REACH, SIDE



Overhead reach: a functional target

- Reaching to an upper cupboard, arm at **102°**: the arm's weight acts ≈**29 cm** from the joint, ≈**10 N·m** before anything is lifted.
- In osteoarthritis with an intact cuff, anatomic and reverse replacements gave similar forward elevation and function scores, but rotation differed.

Anatomic vs reverse: range



aTSA vs rTSA; negative values favour anatomic replacement. Six comparative studies (level IV meta-analysis). Kim et al. (2022).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

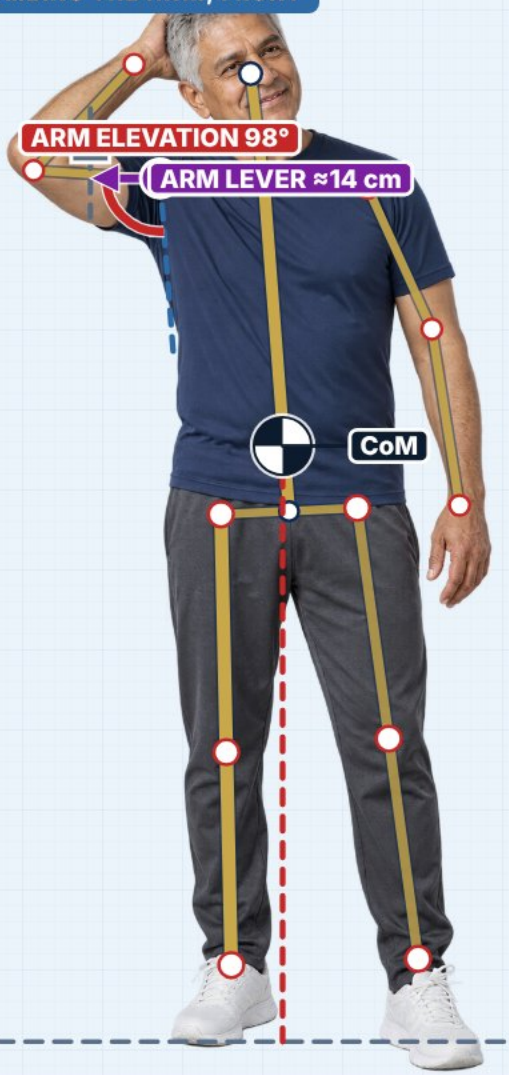
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER SHOULDER REPLACEMENT: REGAINING REACH, STRENGTH AND DAILY FUNCTION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

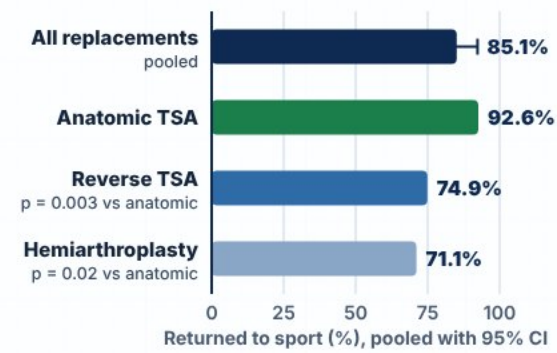
B · COMBING THE HAIR, FRONT



Combing the hair needs rotation

- Hand behind the head, arm at **98°** with a lever of **≈14 cm**: the task combines elevation with external rotation, the movement that tends to favour anatomic replacement.
- Most people return to recreational sport, commonly swimming and golf; implant type and the state of the cuff shape what to expect.

Return to sport by implant



13 studies, 944 patients; mean follow-up 5.1 years; 72.3% returned at the same or a higher level. Liu et al. (2018).

Myth: "After a shoulder replacement you have to give up sport." 85.1% returned in pooled studies.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

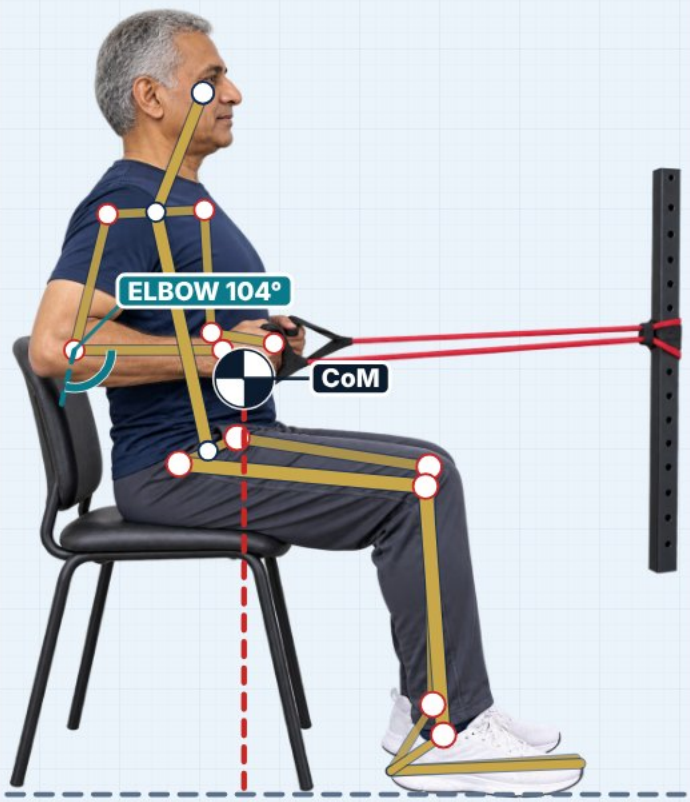
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER SHOULDER REPLACEMENT: REGAINING REACH, STRENGTH AND DAILY FUNCTION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

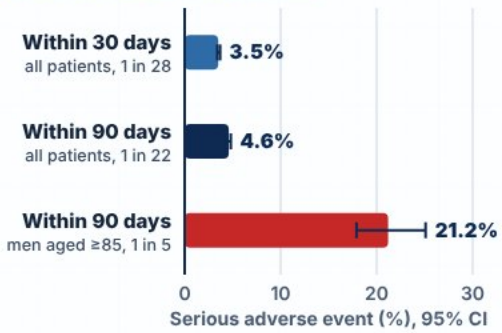
C · SEATED BAND ROW, SIDE



Seated row: pulling strength

- Elbows drawn back to ≈**104°** of flexion against a band while seated: a supported way to rebuild pulling and shoulder-blade strength with easily graded resistance.
- Serious problems in the first weeks are uncommon overall but rise sharply in the very old, so early recovery is a medical as well as a rehabilitation phase.

Early serious adverse events



58,054 elective replacements in adults ≥50 years, England, 1998–2017. Craig et al. (2019).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow angle from pose landmarks. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER SHOULDER REPLACEMENT: REGAINING REACH, STRENGTH AND DAILY FUNCTION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Cupboard reach
≈10 N·m



B · Combing hair
Elevation + rotation



C · Seated row
Elbow ≈104°

Age changes the chance of a second operation



Highest and lowest lifetime revision risks; risk highest in the first five years. Craig et al. (2019).

Decision pathway

1. **EXPECT**
   Set goals by implant type: reach is similar, rotation tends to be better after anatomic replacement.
2. **LOAD**
   Progress from supported pulling and reaching towards daily tasks such as cupboards and hair care.
3. **COUNSEL**
   Discuss age-specific revision and early medical risks as part of a shared decision.

NOT RECOMMENDED

Promising identical rotation after reverse and anatomic replacement.

SEEK ASSESSMENT IF

Calf pain or swelling, chest pain or breathlessness; wound discharge, fever or rising pain; or a sudden clunk with loss of movement or deformity.

REFERENCES (APA 7)

Craig, R. S., Lane, J. C. E., Carr, A. J., Furniss, D., Collins, G. S., & Rees, J. L. (2019). Serious adverse events and lifetime risk of reoperation after elective shoulder replacement: Population based cohort study using hospital episode statistics for England. *BMJ, 364*, l298. https://doi.org/10.1136/bmj.l298

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kim, H., Kim, C.-H., Kim, M., Lee, W., Jeon, I.-H., Lee, K. W., & Koh, K. H. (2022). Is reverse total shoulder arthroplasty (rTSA) more advantageous than anatomic TSA (aTSA) for osteoarthritis with intact cuff tendon? A systematic review and meta-analysis. *Journal of Orthopaedics and Traumatology, 23*, Article 3. https://doi.org/10.1186/s10195-022-00625-y

Liu, J. N., Steinhaus, M. E., Garcia, G. H., Chang, B., Fields, K., Dines, D. M., Warren, R. F., & Gulotta, L. V. (2018). Return to sport after shoulder arthroplasty: A systematic review and meta-analysis. *Knee Surgery, Sports Traumatology, Arthroscopy, 26*(1), 100–112. https://doi.org/10.1007/s00167-017-4547-1

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

MMSx Authority
APPLIED BIOMECHANICS LAB

DOI 10.5281/zenodo.23735725

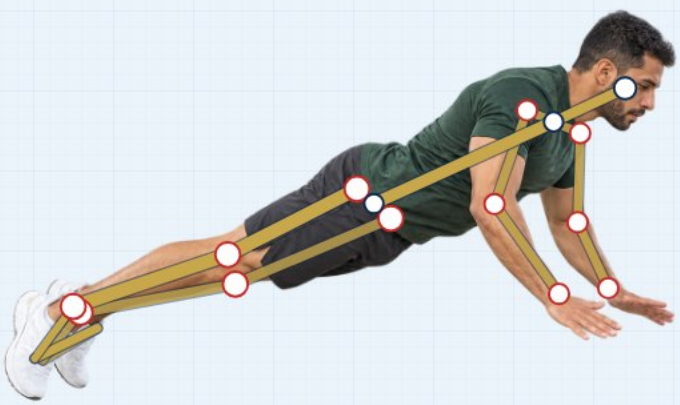
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER A SHOULDER DISLOCATION: RETURNING TO SPORT AND CONTACT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

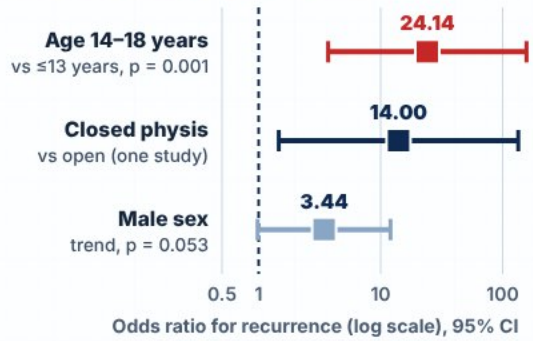
A · PLYOMETRIC PUSH-UP, SIDE



Plyometric push-up: power under load

- Pushing hard enough for the hands to leave the floor, then catching the body again, tests whether the shoulder can absorb and produce force quickly, a late-stage marker before contact.
- In people aged 18 and under, pooled recurrence after a first traumatic dislocation was 73%; teenagers aged 14–18 had 93% versus 40% at 13 or under.

Who is most likely to slip again?



6 retrospective cohort studies, ≤18 years; wide intervals reflect small studies. Olds et al. (2016).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose angles are unreliable in push-up positions. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

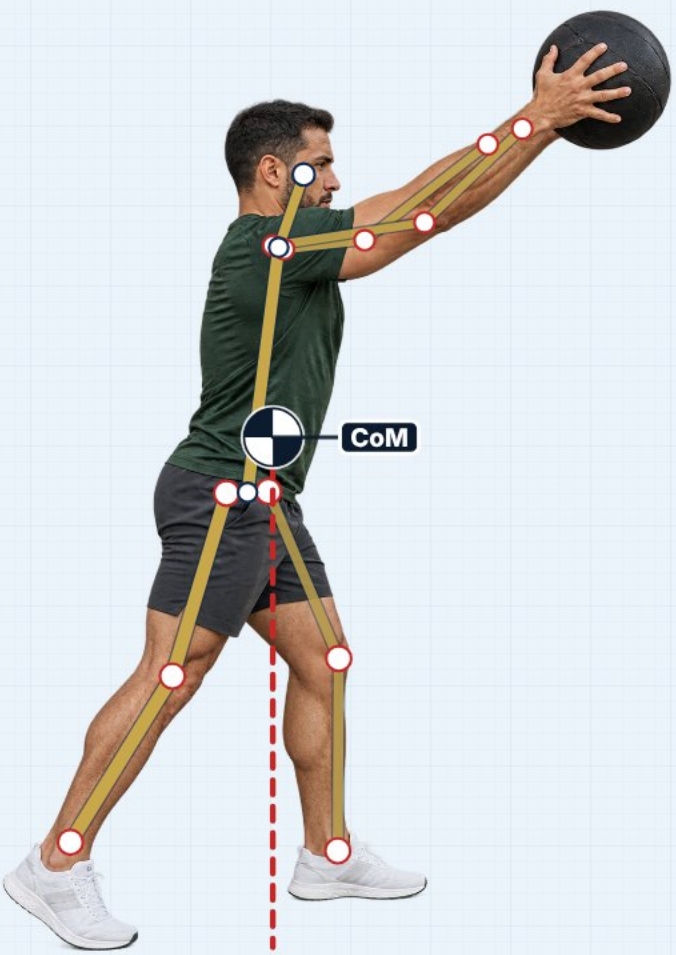
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER A SHOULDER DISLOCATION: RETURNING TO SPORT AND CONTACT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

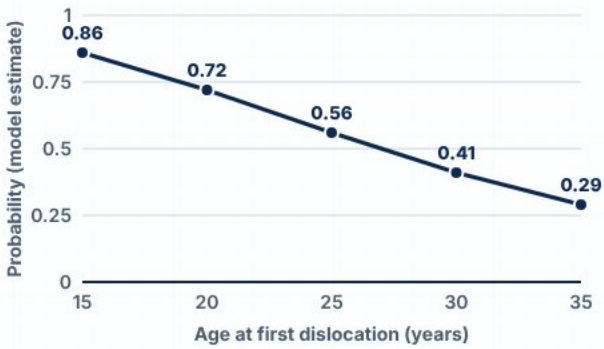
B · OVERHEAD BALL THROW, SIDE



Overhead throw: speed at end range

- Releasing a medicine ball from overhead moves the arm fast through the abducted, rotated positions in which the anterior restraints are most stressed, so it comes late in rehabilitation.
- Almost 90% of recurrences occur within 2 years, and the younger the athlete at the first dislocation, the higher the chance.

Recurrence within 2 years, males



Model estimates for young males after a first traumatic anterior dislocation (Robinson model, reproduced in Table 1). Brownson et al. (2015).

Myth: "Back in and pain-free means safe for contact." Pain-free is not the same as stable.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Oblique view: skeleton and CoM only; angles not measured. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

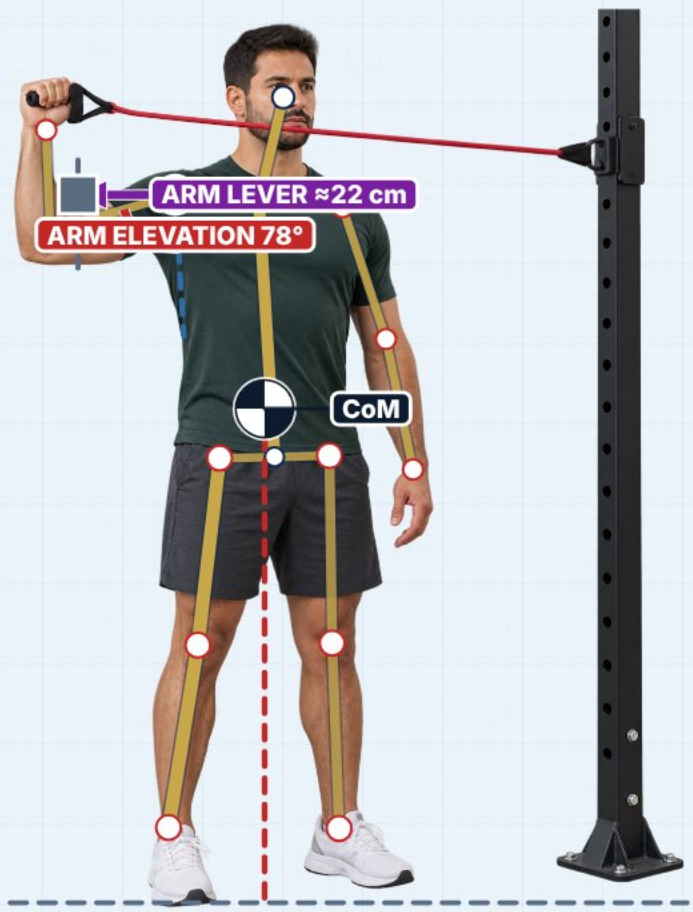
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER A SHOULDER DISLOCATION: RETURNING TO SPORT AND CONTACT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

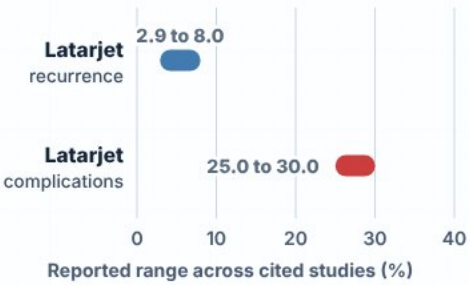
C · 90/90 BAND ROTATION, FRONT



90/90 rotation: the at-risk position

- Arm out at **78°** with the elbow bent, rotating up against a band: the arm's lever (**≈22 cm**, **≈7 N·m**) is held while the cuff controls rotation in the throwing position.
- If surgery is chosen, bone loss changes the operation: glenoid bone loss of about 20% or more is associated with higher recurrence.

Latarjet: fewer slips, more complications



Arthroscopic anchor repair: about 8% recurrence at 2–4 years. Values as summarised in the national pathway. Brownson et al. (2015).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

AFTER A SHOULDER DISLOCATION: RETURNING TO SPORT AND CONTACT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Plyo push-up
Power and catch

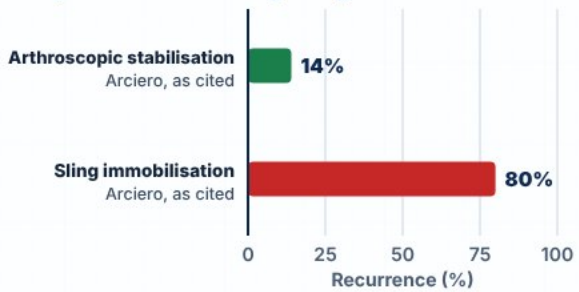


B · Overhead throw
Speed at end range



C · 90/90 rotation
≈7 N·m

Primary stabilisation in young athletes



Arciero trial as cited in the pathway; across 22 RCTs labral repair cut 2-year redislocation (RR 0.15), yet 47% without surgery stayed stable. Brownson et al. (2015); Kavaja et al. (2018).

Decision pathway

1. **DECIDE**
   Weigh age, sex, contact or overhead sport, laxity and bone loss when choosing rehabilitation or stabilisation.
2. **BUILD**
   Progress from cuff strength to plyometric and overhead power before any contact.
3. **CLEAR**
   Return on strength, control and an informed decision, not on being pain-free.

NOT RECOMMENDED

Immobilisation beyond 1 week to prevent recurrence; routine external-rotation bracing.

SEEK ASSESSMENT IF

The shoulder will not relocate, the arm is numb or weak, a fracture is suspected, rotation is weak over age 40, or apprehension recurs in drills.

REFERENCES (APA 7)

Brownson, P., Donaldson, O., Fox, M., Rees, J. L., Rangan, A., Jaggi, A., Tytherleigh-Strong, G., McBernie, J., Thomas, M., & Kulkarni, R. (2015). BESS/BOA patient care pathways: Traumatic anterior shoulder instability. *Shoulder & Elbow, 7*(3), 214–226. https://doi.org/10.1177/1758573215585656

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kavaja, L., Lähdeoja, T., Malmivaara, A., & Paavola, M. (2018). Treatment after traumatic shoulder dislocation: A systematic review with a network meta-analysis. *British Journal of Sports Medicine, 52*(23), 1498–1506. https://doi.org/10.1136/bjsports-2017-098539

Olds, M., Donaldson, K., Ellis, R., & Kersten, P. (2016). In children 18 years and under, what promotes recurrent shoulder instability after traumatic anterior shoulder dislocation? A systematic review and meta-analysis of risk factors. *British Journal of Sports Medicine, 50*, 1135–1141. https://doi.org/10.1136/bjsports-2015-095149

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

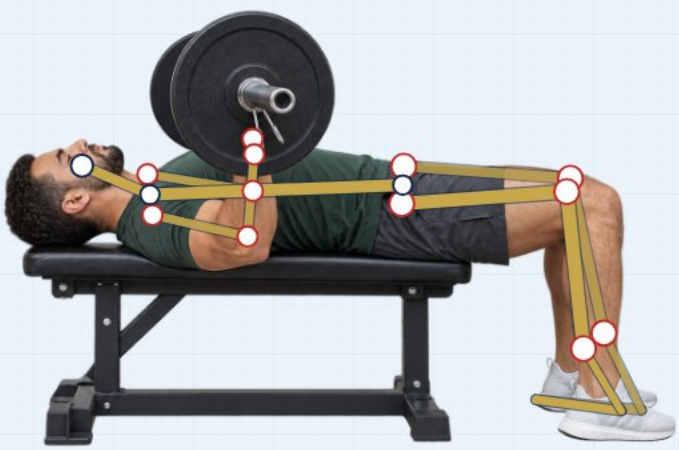
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING BENCH PRESS: GRIP WIDTH, DEPTH AND LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

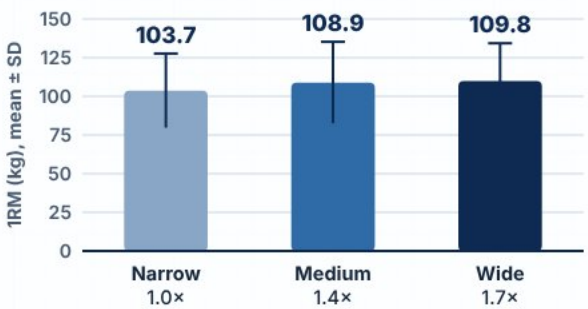
A · WIDE-GRIP BENCH, SIDE



A wide grip at the chest

- With the bar on the chest and the hands far apart, the upper arm sits wide of the trunk; grips wider than 1.5× shoulder (biacromial) width are linked with AC joint, capsule and pectoral problems.
- Grip width is given as a multiple of biacromial distance, so the same rule fits lifters of any size.

Grip width barely changes strength



14 trained men; medium and wide above narrow ($p < 0.001$); chest and anterior deltoid EMG unchanged. Larsen et al. (2021).

Key point: moving from a 1.7× to a 1.4× grip cost about 1 kg of 1RM in this study (109.8 vs 108.9 kg).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Pose landmarks are less reliable in lying positions, so no angles are quoted for this frame. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

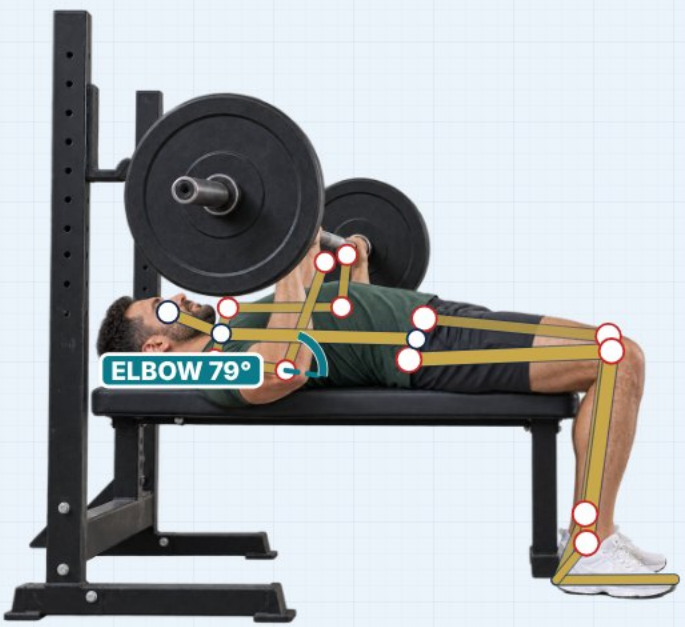
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING BENCH PRESS: GRIP WIDTH, DEPTH AND LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

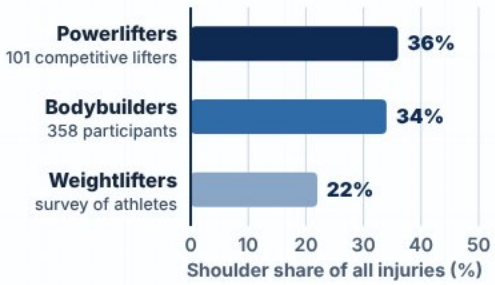
B · MEDIUM-GRIP BENCH, SIDE



Bringing the grip in

- Grip just outside shoulder width, elbow flexed ≈**79°** at the chest: the upper arm stays closer to the trunk than with the wide grip.
- In a shoulder model of 10 strength athletes, a narrower grip reduced AC joint compression, and scapular retraction reduced posterior shear and rotator cuff activity.

The shoulder is a common site in lifters



Primary studies as summarised by Kolber et al. (2010); secondary values. Model data: Noteboom et al. (2024).

Key point: injury rates in weight training are low; shoulder complaints are mostly a load-management problem.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow angle from pose landmarks; less reliable in lying positions, so treat it as approximate. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING BENCH PRESS: GRIP WIDTH, DEPTH AND LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

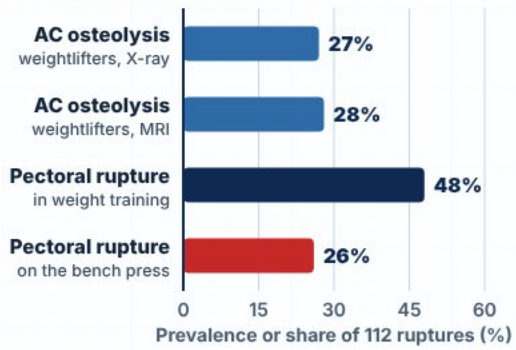
C · LOCKOUT GRIP, FRONT



Which tissues take the strain

- The AC joint and the pectoralis major tendon are the bench-specific tissues: about one in four weightlifters showed distal clavicle osteolysis.
- In a meta-analysis of 112 pectoral ruptures, 54 happened in weight training and 29 on the bench press itself.

AC joint and pectoral tendon



Secondary values from Kolber et al. (2010); ruptures 54/112 and 29/112 of cases in one meta-analysis.

Myth: "A wide grip is always stronger, so it is always better." Grips at or below 1.5× keep strength within about ±5% (Green & Comfort, 2007).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only; no measurements are taken from this foot-end view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING BENCH PRESS: GRIP WIDTH, DEPTH AND LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Wide grip
Upper arm wide of trunk

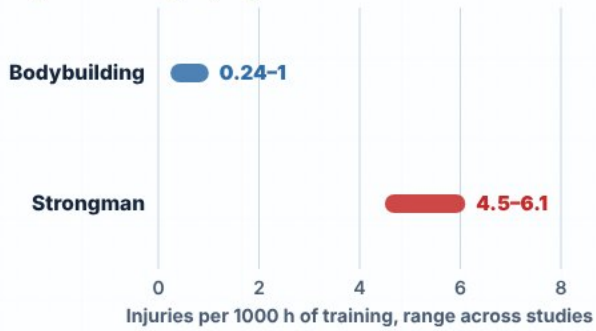


B · Medium grip
Elbow ≈79°



C · Lockout
Grip width visible

Weight training injury rates are low



Systematic review across weight-training sports; the shoulder is among the most injured sites. Keogh & Winwood (2017).

Decision pathway

1. **GRIP**
   Keep the grip at about 1.5× biacromial width or narrower while the shoulder is sensitive.
2. **RANGE**
   Shorten the descent and avoid extreme end range; set the shoulder blades back.
3. **BALANCE**
   Add posterior shoulder stretching and external-rotator and scapular work; review if no better by 12 weeks.

NOT RECOMMENDED

Repeated steroid injections; decompression surgery as first-line care.

SEEK ASSESSMENT IF

A sudden tearing feeling with bruising or a change in chest or armpit shape, a suspected fracture or dislocation, infection, a lump, or several inflamed joints.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Green, C., & Comfort, P. (2007). The affect of grip width on bench press performance and risk of injury. *Strength and Conditioning Journal, 29*(5), 10–14. https://doi.org/10.1519/00126548-200710000-00001

Keogh, J. W. L., & Winwood, P. W. (2017). The epidemiology of injuries across the weight-training sports. *Sports Medicine, 47*(3), 479–501. https://doi.org/10.1007/s40279-016-0575-0

Kolber, M. J., Beekhuizen, K. S., Cheng, M.-S. S., & Hellman, M. A. (2010). Shoulder injuries attributed to resistance training: A brief review. *Journal of Strength and Conditioning Research, 24*(6), 1696–1704. https://doi.org/10.1519/JSC.0b013e3181dc4330

Larsen, S., Gomo, O., & van den Tillaar, R. (2021). A biomechanical analysis of wide, medium, and narrow grip width effects on kinematics, horizontal kinetics, and muscle activity on the sticking region in recreationally trained males during 1-RM bench pressing. *Frontiers in Sports and Active Living, 2*, 637066. https://doi.org/10.3389/fspor.2020.637066

Noteboom, L., Belli, I., Hoozemans, M. J. M., Seth, A., Veeger, H. E. J., & van der Helm, F. C. T. (2024). Effects of bench press technique variations on musculoskeletal shoulder loads and potential injury risk. *Frontiers in Physiology, 15*, 1393235. https://doi.org/10.3389/fphys.2024.1393235

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

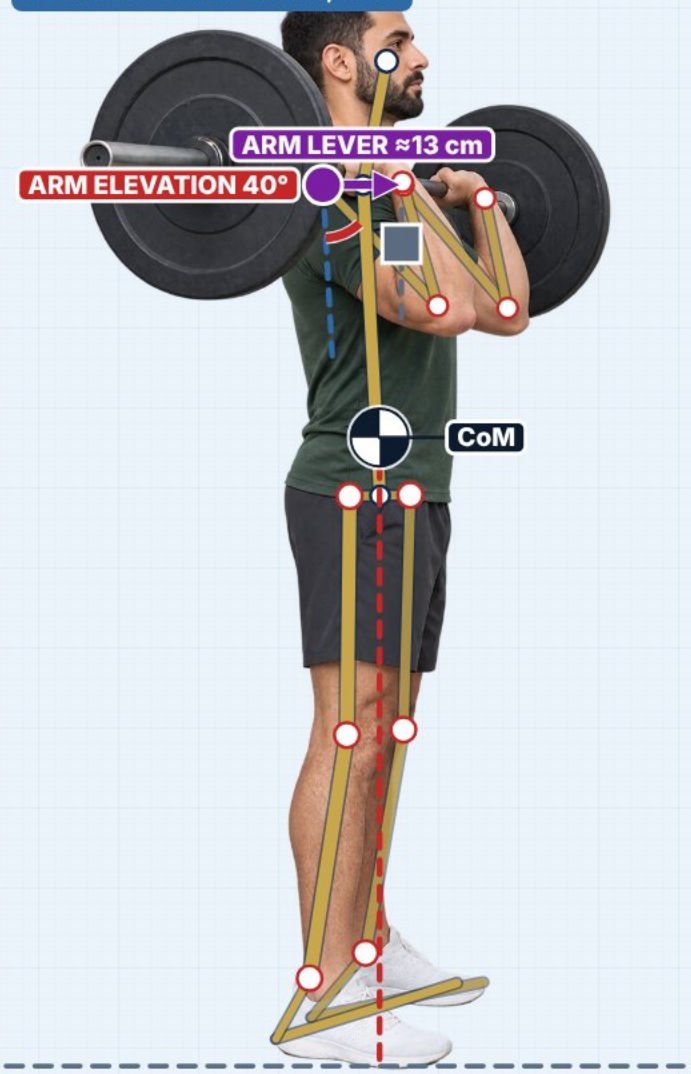
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING OVERHEAD PRESS: RANGE, BAR PATH AND TRUNK POSITION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

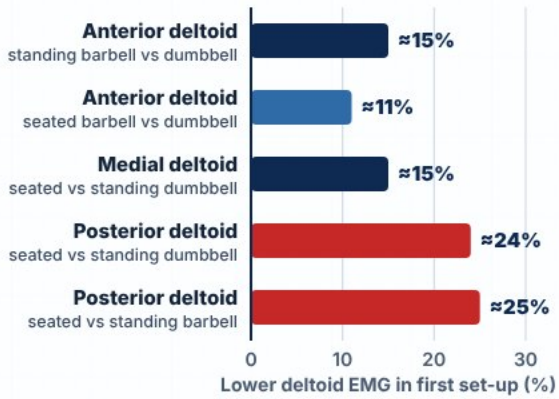
A · BAR AT COLLARBONE, SIDE



The start: bar at the collarbone

- Upper arm at **40°** with the elbows slightly forward: the arm's own weight acts **≈13 cm** from the joint, **≈5 N·m** before any bar load.
- Weight trainers showed more painful-arc and Hawkins–Kennedy findings than controls; lateral raises and upright rows above 90° were associated with them.

Set-up is a dose dial



15 healthy men at 80% 1RM; all differences shown $p \leq 0.05$. Saeterbakken & Fimland (2013). Trainer data: Kolber et al. (2014).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Bar load not included. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING OVERHEAD PRESS: RANGE, BAR PATH AND TRUNK POSITION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

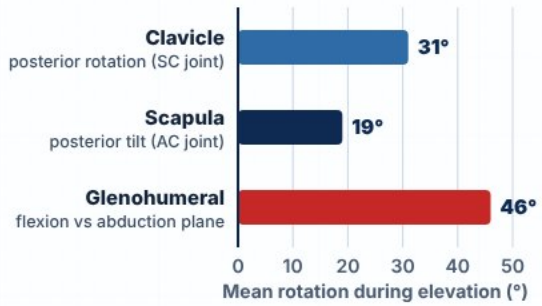
B · OVERHEAD LOCKOUT, SIDE



Lockout: the load stacks over the joint

- Bar locked out, arm at **174°**: the arm's centre of mass sits only **≈2 cm** from the joint, so the static moment is small.
- Reaching full overhead needs the clavicle, scapula and glenohumeral joint to rotate together; the bar path plane changes what the joint must do.

Overhead is a whole-complex position



12 adults, sensors fixed to bone by pins; last row is the largest plane difference. Ludewig et al. (2009).

Key point: pain near lockout is not proof that the glenohumeral joint itself is damaged.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Bar load not included. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

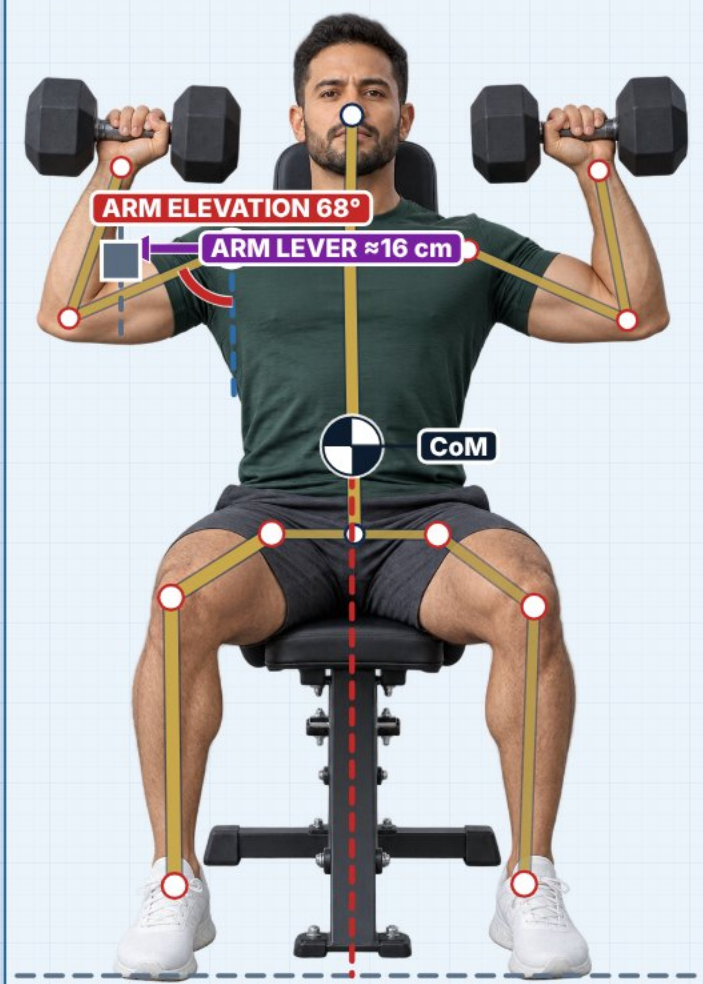
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING OVERHEAD PRESS: RANGE, BAR PATH AND TRUNK POSITION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

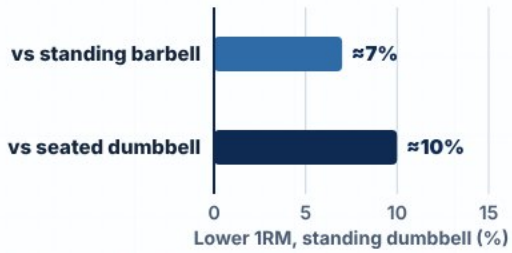
C · SEATED DB PRESS, FRONT



Seated dumbbells: arm out to the side

- Dumbbells at ear height, upper arm at **68°** from the trunk: arm lever **≈16 cm**, **≈5 N·m** from the arm alone.
- Sitting lowered medial and posterior deltoid activity against standing; the least stable set-up loads the deltoid most but allows the lightest weight.

"Heavier" is not "more shoulder"



Same 15 men; p = 0.002 and p < 0.001. Saeterbakken & Fimland (2013).

Myth: "If it hurts overhead, stop pressing for good." Exercise is first-line care; set-up, range and load can usually be changed instead.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Dumbbell load not included. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

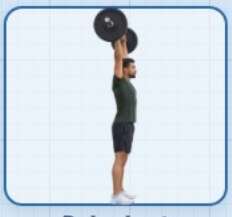
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING OVERHEAD PRESS: RANGE, BAR PATH AND TRUNK POSITION

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Start
Lever ≈13 cm



B · Lockout
Arm 174°



C · Seated DB
≈5 N·m, arm only

When to change the plan



UK subacromial pain pathway; injection benefit is transient (<12 weeks); surgery only after 6 months, not first-line. Pandey et al. (2025).

Decision pathway

1. **SET-UP**
   Use seated or barbell pressing to lower deltoid demand while symptoms settle.
2. **RANGE**
   Limit lateral raises and upright rows above 90°; strengthen the external rotators.
3. **PROGRESS**
   Return range and load step by step; seek review if no better by 12 weeks.

NOT RECOMMENDED

Repeated steroid injections; decompression surgery as first-line care.

SEEK ASSESSMENT IF

A suspected fracture or dislocation after injury, signs of infection, a lump or swelling, several inflamed joints, or a child or adolescent with shoulder pain.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kolber, M. J., Cheatham, S. W., Salamh, P. A., & Hanney, W. J. (2014). Characteristics of shoulder impingement in the recreational weight-training population. *Journal of Strength and Conditioning Research, 28*(4), 1081–1089. https://doi.org/10.1519/JSC.0000000000000250

Ludewig, P. M., Phadke, V., Braman, J. P., Hassett, D. R., Cieminski, C. J., & LaPrade, R. F. (2009). Motion of the shoulder complex during multiplanar humeral elevation. *Journal of Bone and Joint Surgery (American Volume), 91*(2), 378–389. https://doi.org/10.2106/JBJS.G.01483

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Saeterbakken, A. H., & Fimland, M. S. (2013). Effects of body position and loading modality on muscle activity and strength in shoulder presses. *Journal of Strength and Conditioning Research, 27*(7), 1824–1831. https://doi.org/10.1519/JSC.0b013e318276b873

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING PUSH-UPS: HAND POSITION AND SCAPULAR CONTROL

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

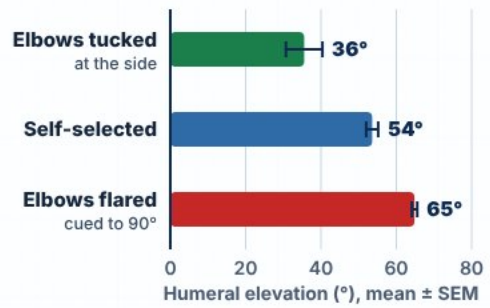
A · PUSH-UP BOTTOM, SIDE



The bottom position

- At the bottom, the hands carry most of the body weight and the shoulder is near its deepest extension, the usual point where a sensitive shoulder complains.
- Elbow position sets how far the upper arm is raised from the trunk: tucking the elbows keeps the arm lower than flaring them.

Tucked elbows, less arm elevation



16 healthy adults, electromagnetic tracking, concentric phase; the "flared" cue reached about 65°. Suprak et al. (2013).

Key point: less arm elevation means less end-range loading of the subacromial region, a useful option while symptoms settle.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: pose landmarks are unreliable in a prone push-up, so no angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

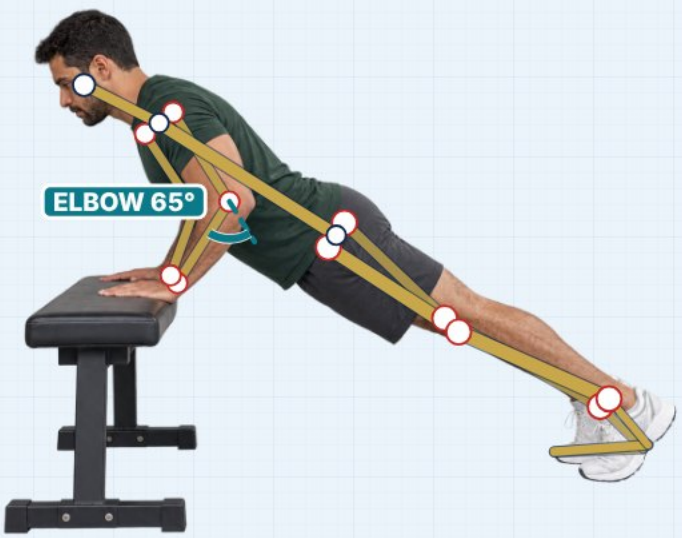
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING PUSH-UPS: HAND POSITION AND SCAPULAR CONTROL

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

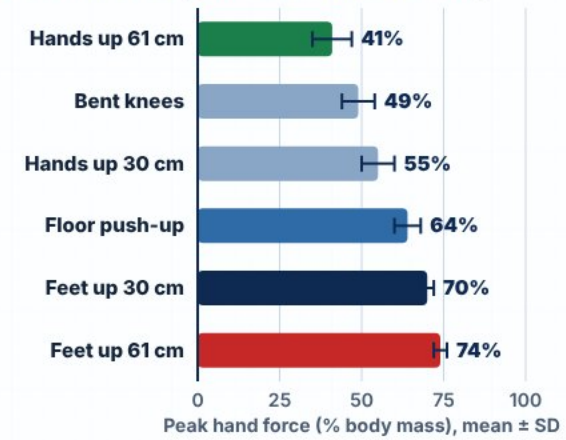
B · INCLINE PUSH-UP, SIDE



Raise the hands to lower the load

- Hands on a bench, body straight, elbow flexed ≈**65°**: more of the body weight passes to the feet.
- Body angle is the simplest dose dial: incline, then knees, then floor, then feet raised.

How much body mass the hands carry



23 fit young adults on a force platform; heights 60.96 and 30.48 cm. Wurm et al. (2010).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow angle from pose landmarks; prone positions reduce reliability, so treat it as approximate. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING PUSH-UPS: HAND POSITION AND SCAPULAR CONTROL

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

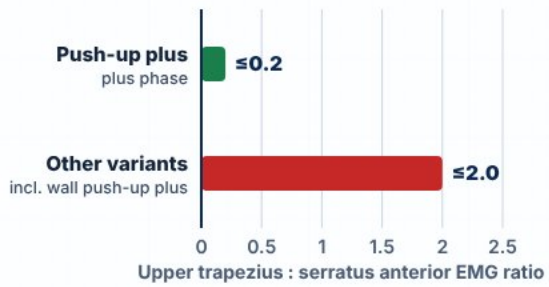
C · WIDE-HAND PUSH-UP, FRONT



Wide hands and the shoulder blade

- With the hands well outside the shoulders, the upper arms are raised further from the trunk; the serratus anterior must hold the shoulder blade against the ribs.
- Adding a "plus" (pushing the upper back up at the top) biases the serratus over the upper trapezius.

The plus phase gives the best balance



30 adults, healthy or mild dysfunction; serratus activity peaked at 123% MVIC in the standard push-up plus. Ludewig et al. (2004).

Myth: "If push-ups hurt, stop them until the pain is gone." Raising the hands and tucking the elbows usually lets the exercise be scaled instead.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). No overlay or measurements: pose landmarks are unreliable in this prone front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN DURING PUSH-UPS: HAND POSITION AND SCAPULAR CONTROL

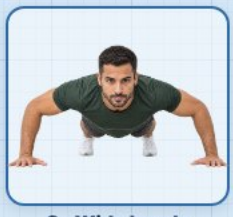
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Floor
64% of body mass



B · Incline
As low as 41%



C · Wide hands
Arms raised further

When to change the plan



UK subacromial pain pathway; exercise first, injection benefit is transient (<12 weeks). Pandey et al. (2025).

Decision pathway

1. **ANGLE**
   Start at an incline the shoulder tolerates, then progress to knees, floor and feet raised.
2. **ELBOWS**
   Tuck the elbows towards the body to keep the upper arm lower.
3. **PLUS**
   Add the plus phase at the top to train serratus anterior control of the shoulder blade.

NOT RECOMMENDED

Repeated steroid injections; surgery as first-line care.

SEEK ASSESSMENT IF

A suspected fracture or dislocation after injury, signs of infection, a lump or swelling, several inflamed joints, a child or adolescent, or no improvement after 12 weeks.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Ludewig, P. M., Hoff, M. S., Osowski, E. E., Meschke, S. A., & Rundquist, P. J. (2004). Relative balance of serratus anterior and upper trapezius muscle activity during push-up exercises. *American Journal of Sports Medicine, 32*(2), 484–493. https://doi.org/10.1177/0363546503258911

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Suprak, D. N., Bohannon, J., Morales, G., Stroschein, J., & San Juan, J. (2013). Scapular kinematics and shoulder elevation in a traditional push-up. *Journal of Athletic Training, 48*(6), 826–835. https://doi.org/10.4085/1062-6050-48.5.08

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Wurm, B., VanderZanden, T. L., Spadavecchia, M., Durocher, J., Bickham, C., Petushek, E. J., & Ebben, W. P. (2010). Kinetic analysis of several variations of push-ups. In *ISBS – Conference Proceedings Archive* (28th International Conference on Biomechanics in Sports). https://ojs.ub.uni-konstanz.de/cpa/article/view/4457

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

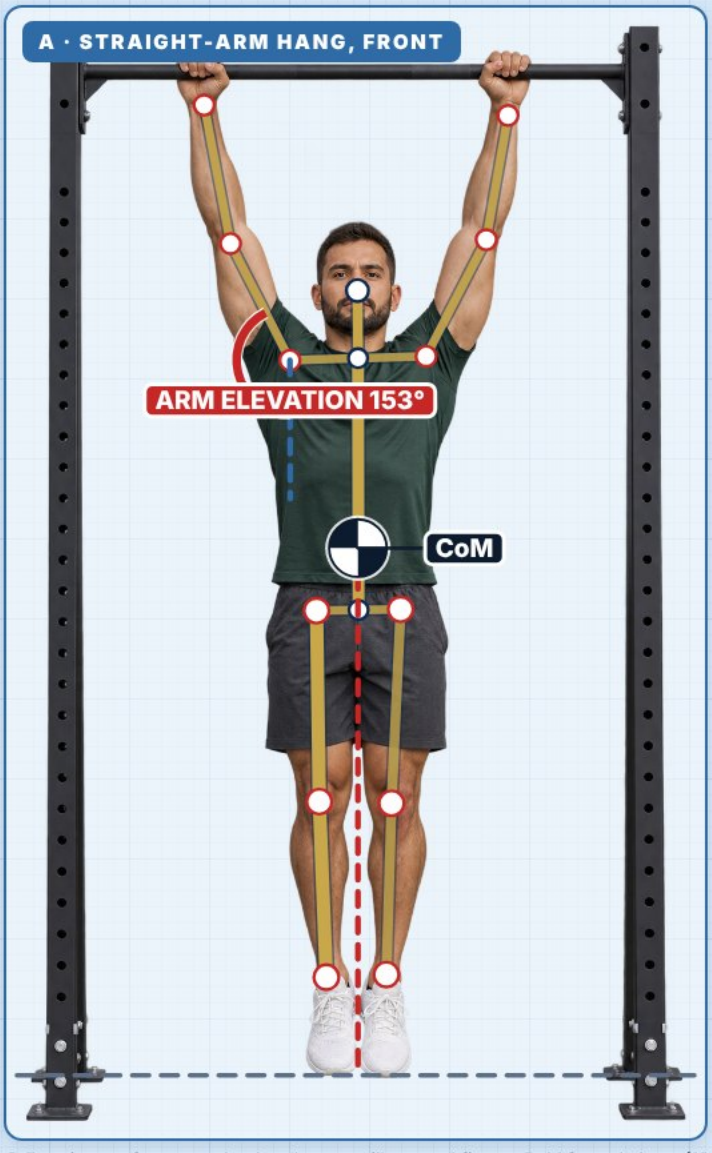
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PULL-UPS AND HANGING WITH SHOULDER PAIN: BUILDING TOLERANCE SAFELY

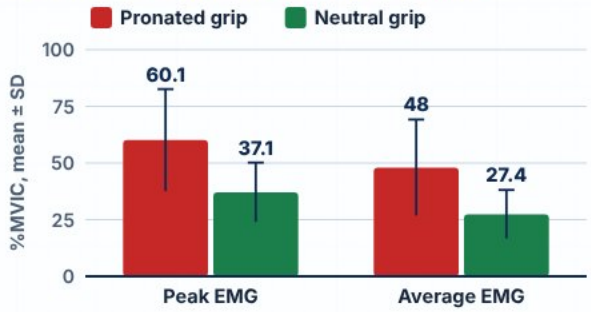
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Hanging is a load, not a rest

- Straight-arm hang, arms at **153°**: body weight pulls through the hands with the rotator cuff working near the top of its range.
- Modelling shows hanging and pulling load the cuff at high elevation; the reverse grip proportionally raised rotator cuff activation.

Grip changes middle trapezius demand



19 strength-trained men; pronated above neutral (P = 0.004 and 0.001). Dickie et al. (2017). Model: Urbanczyk et al. (2020).

Myth: "Dead hangs decompress and fix a painful shoulder." No verified study shows this; hangs are a load to be dosed.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation from pose landmarks, relative to the vertical. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

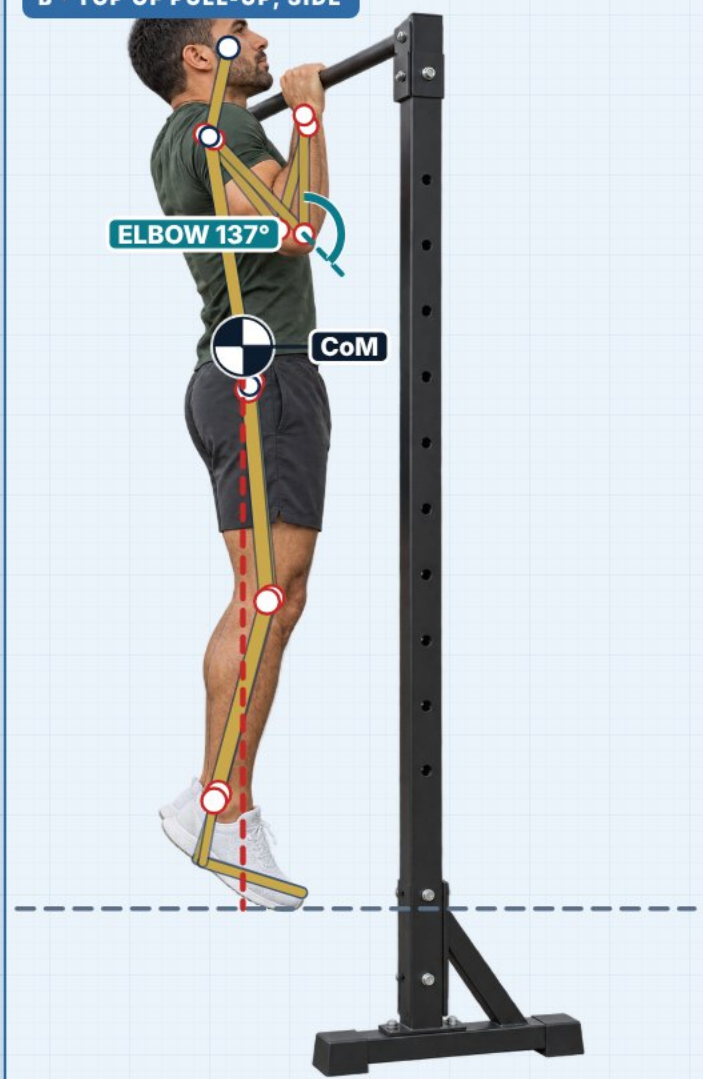
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PULL-UPS AND HANGING WITH SHOULDER PAIN: BUILDING TOLERANCE SAFELY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

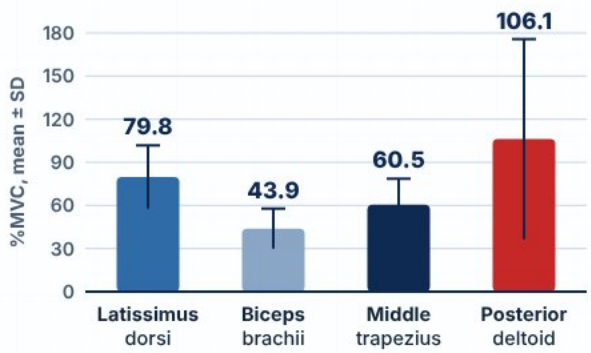
B · TOP OF PULL-UP, SIDE



The top: a high-demand position

- Chin over the bar, elbow flexed ≈**137°** with the upper arm drawn down to the side; lowering from here loads the supraspinatus, deltoid and triceps eccentrically.
- Posterior deltoid and latissimus work hard whatever the handle; grip mainly changes comfort.

Standard pull-up muscle demand



15 resistance-trained adults; strap and towel versions were similar, except less middle trapezius with a towel. Snarr et al. (2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Elbow angle from pose landmarks on an illustrated figure; approximate. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

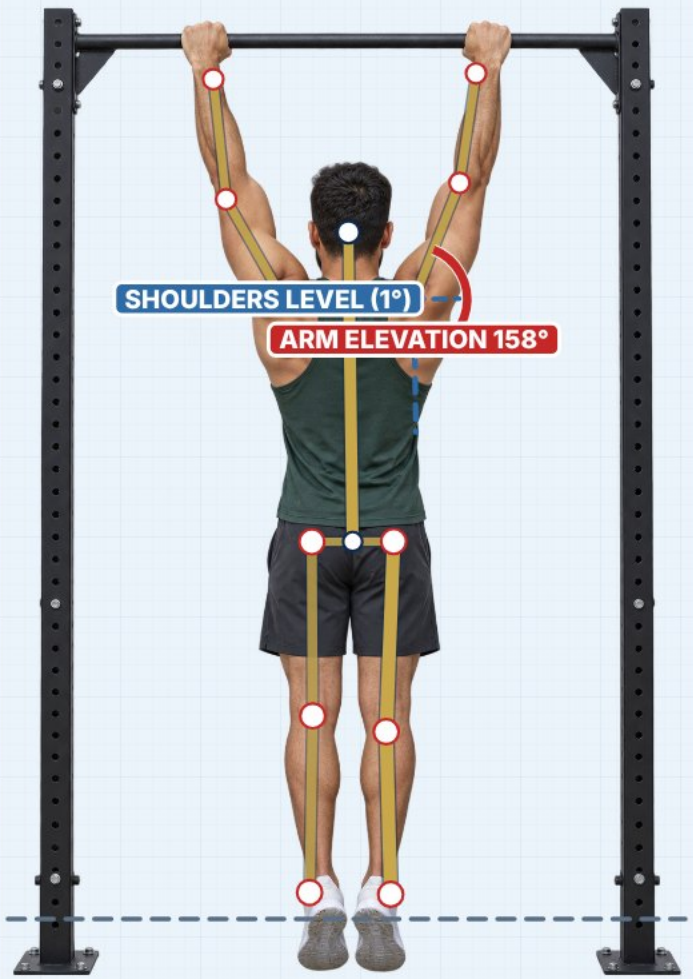
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PULL-UPS AND HANGING WITH SHOULDER PAIN: BUILDING TOLERANCE SAFELY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

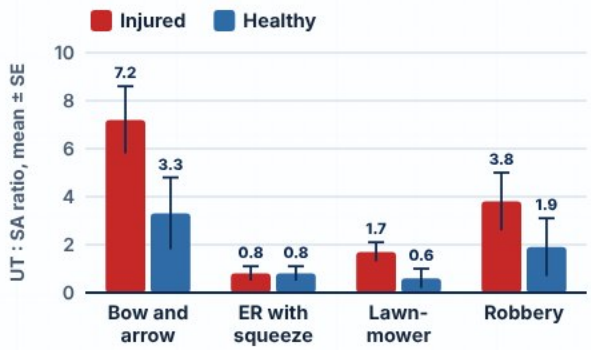
C · SCAPULAR HANG, REAR



Shoulder blades down, elbows straight

- Active hang, arms at **158°**, shoulders level (**1°**): pulling the shoulder blades down without bending the elbows builds control before full pull-ups.
- External rotation with a scapular squeeze gave the most balanced upper trapezius to serratus ratio in injured and healthy shoulders.

Scapular drills before pull-ups



20 injured and 19 healthy adults; drills differed (P < .001), groups did not. Moeller et al. (2014).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and shoulder line from pose landmarks in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PULL-UPS AND HANGING WITH SHOULDER PAIN: BUILDING TOLERANCE SAFELY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Dead hang
Arms 153°

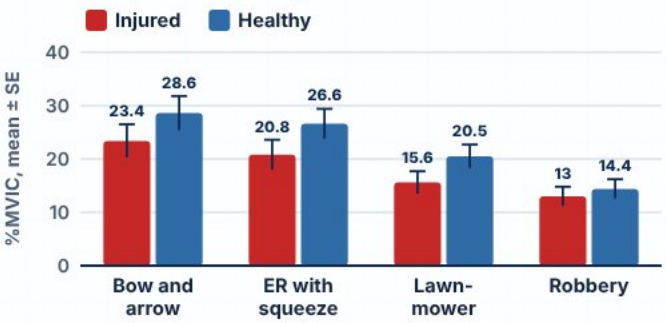


B · Top position
Elbow ≈137°



C · Scapular hang
Shoulders level

Lower trapezius in scapular drills



Same 39 adults; group differences were not significant. Moeller et al. (2014).

Decision pathway

1. **CONTROL**
   Start with scapular drills such as external rotation with a scapular squeeze.
2. **HANG**
   Add active hangs with the shoulder blades drawn down, then assisted or slow-lowering pull-ups.
3. **GRIP**
   Use a neutral or reverse grip if overhand hurts; build range and volume over weeks.

NOT RECOMMENDED

Repeated steroid injections; surgery as first-line care.

SEEK ASSESSMENT IF

Sudden loss of the ability to lift the arm after a hang or fall, a suspected dislocation or fracture, infection, a lump, or no improvement after 12 weeks.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Dickie, J., Faulkner, J., Barnes, M., & Lark, S. (2017). Electromyographic analysis of muscle activation during pull-up variations. *Journal of Electromyography and Kinesiology, 32*, 30–36. https://doi.org/10.1016/j.jelekin.2016.11.004

Moeller, C. R., Huxel Bliven, K. C., & Snyder Valier, A. R. (2014). Scapular muscle-activation ratios in patients with shoulder injuries during functional shoulder exercises. *Journal of Athletic Training, 49*(3), 345–355. https://doi.org/10.4085/1062-6050-49.3.10

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Snarr, R. L., Hallmark, A. V., Casey, J. C., & Esco, M. R. (2017). Electromyographical comparison of a traditional, suspension device, and towel pull-up. *Journal of Human Kinetics, 58*, 5–13. https://doi.org/10.1515/hukin-2017-0068

Urbanczyk, C. A., Prinold, J. A. I., Reilly, P., & Bull, A. M. J. (2020). Avoiding high-risk rotator cuff loading: Muscle force during three pull-up techniques. *Scandinavian Journal of Medicine & Science in Sports, 30*(11), 2205–2214. https://doi.org/10.1111/sms.13780

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

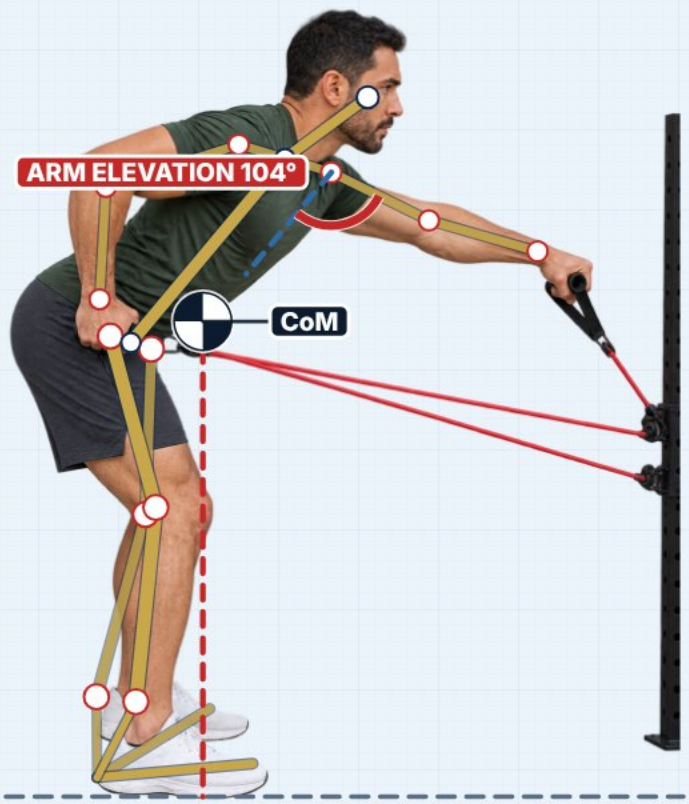
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SWIMMER'S SHOULDER: STROKE VOLUME, TECHNIQUE AND FATIGUE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

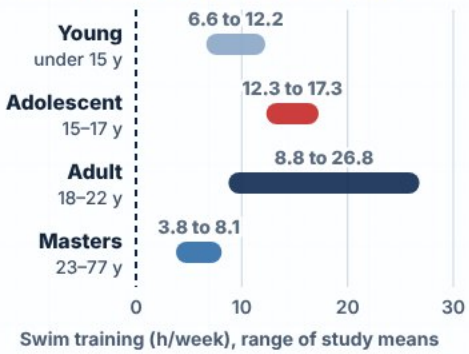
A · BAND FREESTYLE PULL, SIDE



One stroke, thousands of times

- Trunk bent **40°** forward, pulling arm at **104°**: the band drill copies the freestyle pull, a motion repeated thousands of times a week in training.
- Of 80 elite swimmers, 91% reported shoulder pain; 69% of the 52 scanned had supraspinatus tendinopathy.

Weekly volume peaks from 15 to 22 years



12 studies, 1460 competitive swimmers. Feijen et al. (2020). Elite data: Sein et al. (2010).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and trunk lean (not drawn) from pose landmarks, relative to the vertical. Educational, not diagnostic.

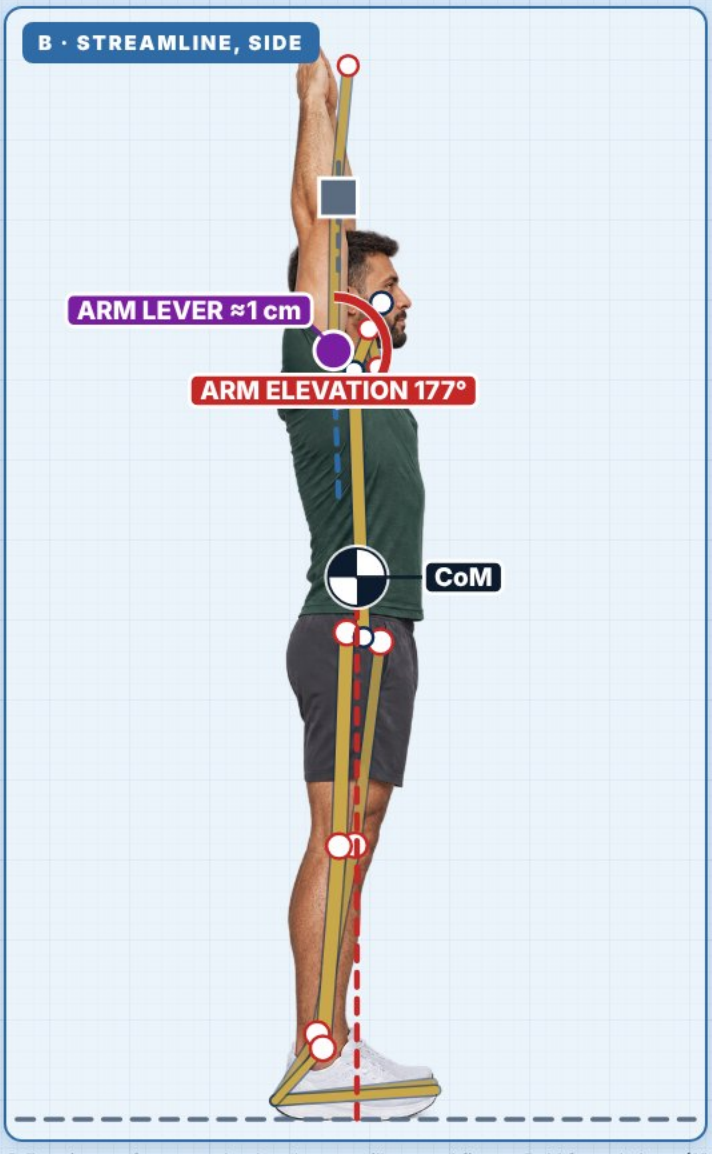
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SWIMMER'S SHOULDER: STROKE VOLUME, TECHNIQUE AND FATIGUE

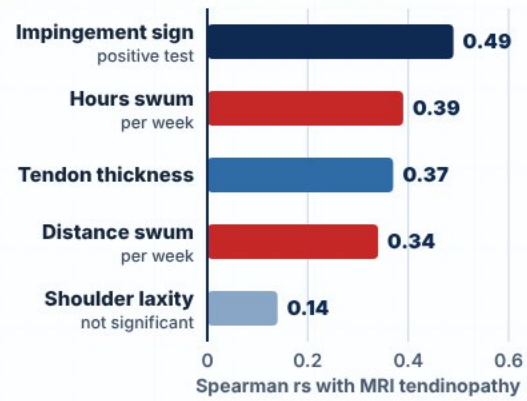
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Streamline: little lever, lots of repeats

- Arms squeezed overhead at **177°**: the arm's centre of mass sits ≈**1 cm** from the joint, so the static moment is small.
- The strain comes from repetition at high elevation: tendon change tracked hours and distance swum, not laxity.

What tendinopathy tracks with



80 elite swimmers aged 13–25, 52 with MRI; laxity p = 0.32. Sein et al. (2010).

Myth: "Swimmer's shoulder is caused by loose shoulders." Laxity was only weakly linked; volume is the main modifiable factor.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SWIMMER'S SHOULDER: STROKE VOLUME, TECHNIQUE AND FATIGUE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

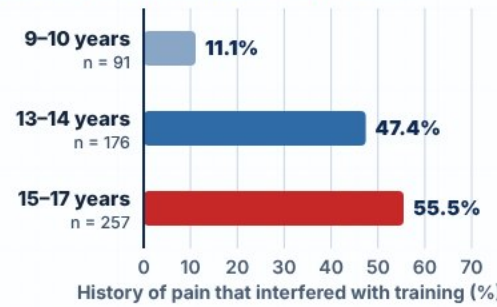
C · PRONE Y RAISE, REAR



Building the shoulder that swims

- Chest supported on the bench, arms raised in a Y at **120°**, shoulders level (**0°**): a scapular strength drill for the lower and middle trapezius.
- Middle trapezius and internal-rotator weakness were risk factors; taking part in another sport was protective.

Pain history climbs in the early teens



Youth club swimmers; a prior episode was the strongest predictor of current disability. Stirling et al. (2024). Risk factors: Tate et al. (2012).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation and shoulder line from pose landmarks in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

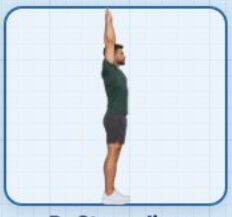
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SWIMMER'S SHOULDER: STROKE VOLUME, TECHNIQUE AND FATIGUE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Pull drill
Trunk 40° forward

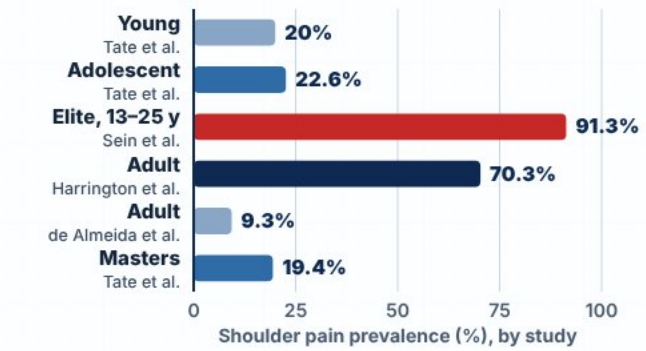


B · Streamline
Lever ≈1 cm



C · Prone Y
Arms 120°

Prevalence depends on definition



Selected studies as cited in Feijen et al. (2020); definitions differ.

Decision pathway

1. **VOLUME**
   Track swim volume all year and avoid sudden large increases.
2. **BUILD**
   Strengthen the middle trapezius and internal rotators, train core endurance and keep another sport.
3. **REHAB**
   Treat persisting pain with exercise first; refer if no better by 12 weeks.

NOT RECOMMENDED

Treating laxity alone as the cause; repeated steroid injections.

SEEK ASSESSMENT IF

Pain that stops sessions or persists between them, a child or adolescent with ongoing pain, a suspected dislocation, infection or a lump.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Feijen, S., Tate, A., Kuppens, K., Claes, A., & Struyf, F. (2020). Swim-training volume and shoulder pain across the life span of the competitive swimmer: A systematic review. *Journal of Athletic Training, 55*(1), 32–41. https://doi.org/10.4085/1062-6050-439-18

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Sein, M. L., Walton, J., Linklater, J., Appleyard, R., Kirkbride, B., Kuah, D., & Murrell, G. A. C. (2010). Shoulder pain in elite swimmers: Primarily due to swim-volume-induced supraspinatus tendinopathy. *British Journal of Sports Medicine, 44*(2), 105–113. https://doi.org/10.1136/bjsm.2008.047282

Stirling, B. D., Sum, J. C., Baek, L., Michener, L. A., Barrack, A. J., & Tate, A. R. (2024). Shoulder pain in competitive swimmers: A multi-site survey study. *International Journal of Sports Physical Therapy, 19*(8), 965–975. https://doi.org/10.26603/001c.121114

Tate, A., Turner, G. N., Knab, S. E., Jorgensen, C., Strittmatter, A., & Michener, L. A. (2012). Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. *Journal of Athletic Training, 47*(2), 149–158. https://doi.org/10.4085/1062-6050-47.2.149

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

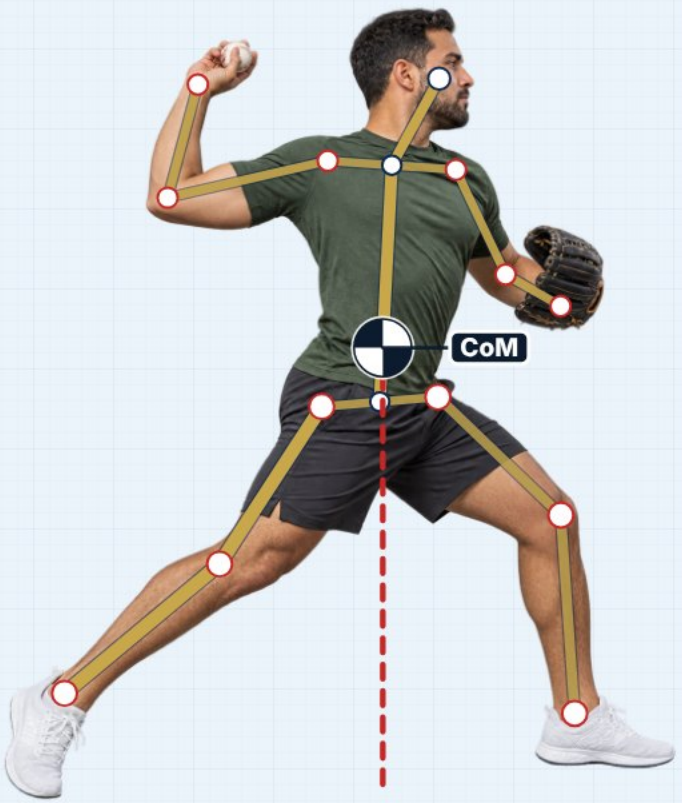
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THROWING SHOULDER: WHY THE WHOLE KINETIC CHAIN MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

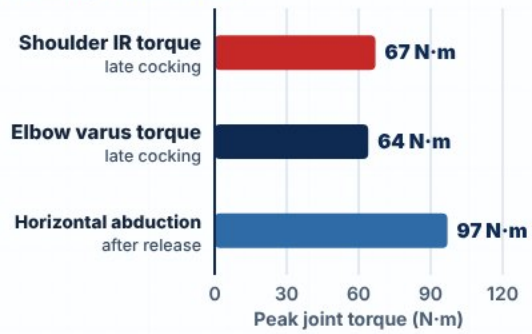
A · LATE COCKING, SIDE



Late cocking: the arm is wound back

- Front foot planted, throwing arm fully cocked: the shoulder is at maximum external rotation, where torque and anterior shear load the labrum, capsule and medial elbow.
- In skilled pitchers, glenohumeral anterior force reached about 380 N during arm cocking.

Two danger instants



26 skilled adult pitchers; high-speed motion analysis and inverse dynamics. Fleisig et al. (1995).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic oblique pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

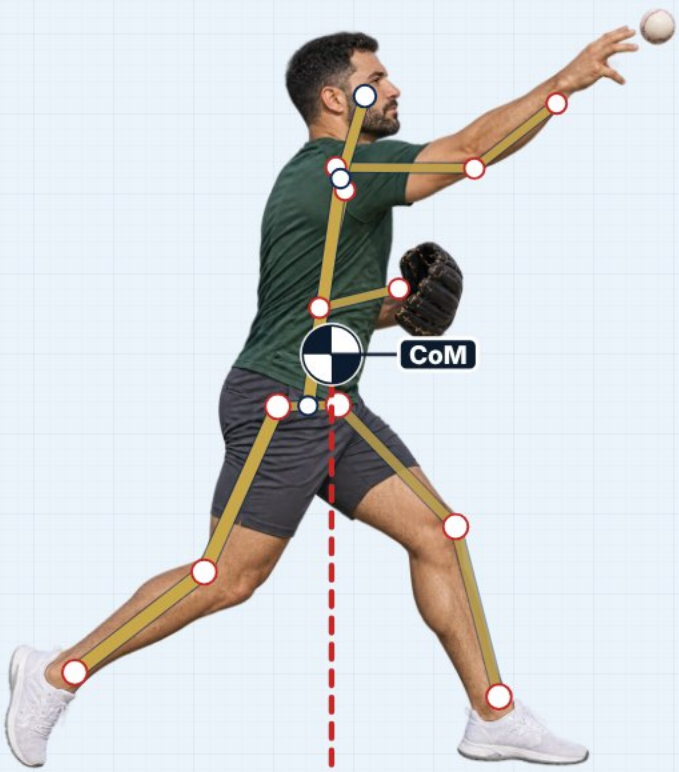
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THROWING SHOULDER: WHY THE WHOLE KINETIC CHAIN MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

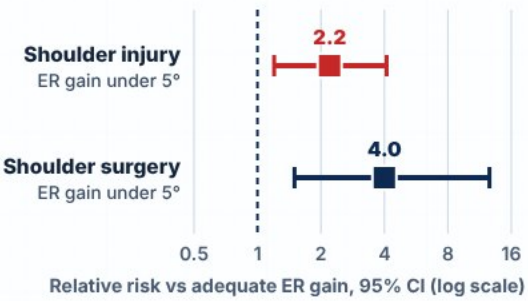
B · BALL RELEASE, SIDE



Release: the trunk sets up the arm

- With an improper trunk rotation sequence, high-school pitchers reached 7.2° more shoulder external rotation and 9.2% of body weight more distraction force.
- Losing the normal external-rotation gain on the throwing side predicted injury; internal-rotation deficit alone did not.

External-rotation gain and injury



296 professional pitchers, 505 exams over 8 seasons. Wilk et al. (2015). Sequence data: Oyama et al. (2014).

Key point: poor sequencing shows up as extra load at the shoulder, an association that makes trunk and pelvis training worth checking.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic oblique pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THROWING SHOULDER: WHY THE WHOLE KINETIC CHAIN MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

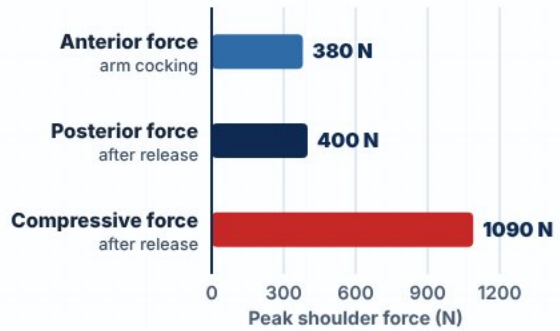
C · FOLLOW-THROUGH, FRONT



Follow-through: braking the arm

- After release the arm crosses the body while the back leg comes through; the cuff and posterior muscles must slow the arm and hold it in the socket.
- About 1090 N of compressive force was needed shortly after release to resist the arm being pulled out of the joint.

Deceleration loads are the largest



Same 26 adult pitchers. Fleisig et al. (1995).

Myth: "Throwers are fixed by stretching out internal rotation." In professional pitchers, internal-rotation deficit alone was not linked to injury.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic oblique pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

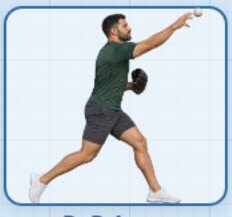
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

THROWING SHOULDER: WHY THE WHOLE KINETIC CHAIN MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Late cocking
Max external rotation

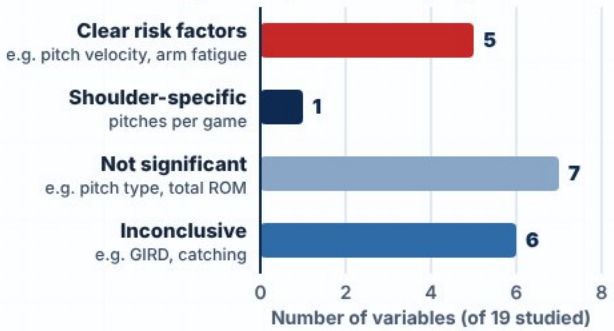


B · Release
Trunk leads the arm



C · Follow-through
Arm decelerates

Youth throwing: what predicts injury



Systematic review of 22 studies in adolescent baseball players. Norton et al. (2019).

Decision pathway

1. **WORKLOAD**
   Limit pitches per game; avoid pitching with arm fatigue or for several teams at once.
2. **RANGE**
   Screen throwing-side external rotation and total motion, not internal rotation alone.
3. **CHAIN**
   Train pelvis and trunk sequencing; for persisting pain, exercise first and refer at 12 weeks.

NOT RECOMMENDED

Using internal-rotation deficit alone as the screening test.

SEEK ASSESSMENT IF

A sudden "dead arm" with loss of velocity or control, night pain, numbness or tingling, a painful pop, or a child or adolescent with ongoing pain.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Fleisig, G. S., Andrews, J. R., Dillman, C. J., & Escamilla, R. F. (1995). Kinetics of baseball pitching with implications about injury mechanisms. *American Journal of Sports Medicine, 23*(2), 233–239. https://doi.org/10.1177/036354659502300218

Norton, R., Honstad, C., Joshi, R., Silvis, M., Chinchilli, V., & Dhawan, A. (2019). Risk factors for elbow and shoulder injuries in adolescent baseball players: A systematic review. *American Journal of Sports Medicine, 47*(4), 982–990. https://doi.org/10.1177/0363546518760573

Oyama, S., Yu, B., Blackburn, J. T., Padua, D. A., Li, L., & Myers, J. B. (2014). Improper trunk rotation sequence is associated with increased maximal shoulder external rotation angle and shoulder joint force in high school baseball pitchers. *American Journal of Sports Medicine, 42*(9), 2089–2094. https://doi.org/10.1177/0363546514536871

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Wilk, K. E., Macrina, L. C., Fleisig, G. S., Aune, K. T., Porterfield, R. A., Harker, P., Evans, T. J., & Andrews, J. R. (2015). Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers. *American Journal of Sports Medicine, 43*(10), 2379–2385. https://doi.org/10.1177/0363546515594380

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

TENNIS AND PADEL SHOULDER PAIN: SERVE MECHANICS AND LOAD MANAGEMENT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

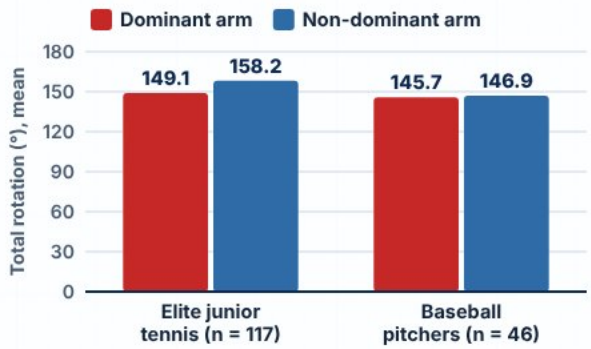
A · SERVE TROPHY, SIDE



Trophy position: the arm is cocked

- Knees bent, tossing arm up, racket arm cocked behind the head: the shoulder moves towards large external rotation before the rapid swing forward.
- Elite junior players had about 9° less total rotation on the racket side; pitchers showed no side difference.

Racket-side rotation is reduced



Passive rotation (internal + external) at 90° abduction; tennis difference P < 0.001, pitchers n.s. Ellenbecker et al. (2002).

Key point: track total rotation on the racket side against the other side, not internal rotation alone.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic oblique pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

TENNIS AND PADEL SHOULDER PAIN: SERVE MECHANICS AND LOAD MANAGEMENT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

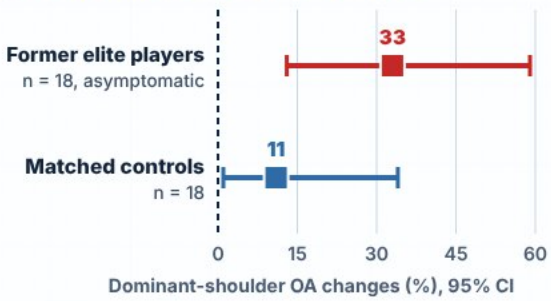
B · SERVE CONTACT, SIDE



Contact: fully stretched overhead

- At ball contact the racket arm is fully extended above the head; after contact the shoulder must decelerate the arm and racket quickly.
- Decades of serving were associated with mild degenerative change in the dominant shoulder, even without symptoms.

Long-term change in former players



Mean age 57.2 y; 5 minimal and 1 moderate change in players; p = 0.04. Maquirriain et al. (2006).

Key point: imaging findings in veteran players should be read alongside symptoms and function, not on their own.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic oblique pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

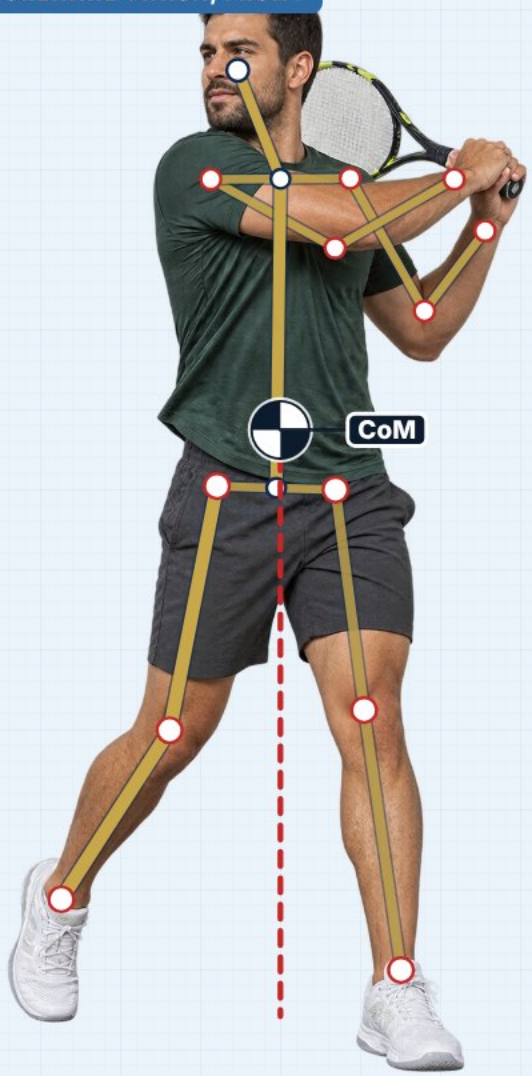
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

TENNIS AND PADEL SHOULDER PAIN: SERVE MECHANICS AND LOAD MANAGEMENT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

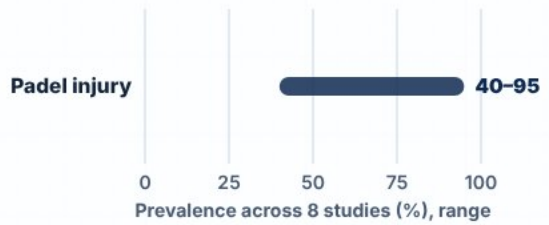
C · FOREHAND FINISH, FRONT



Forehand and padel: more strokes

- The forehand finishes with the racket over the opposite shoulder; ground strokes add to the weekly load the serve already places on the shoulder.
- In padel, injury incidence was 3 per 1000 h of training and 8 per 1000 matches; the shoulder ranked third after the elbow and knee.

Padel injury is common



8 studies, 2022 players, mean age 31–57; tendon and muscle injuries predominated. Dahmen et al. (2023).

Myth: "Serve power comes from the arm, so a sore shoulder needs a stronger arm." Racket speed is built through the legs and trunk as well as the arm; arm strength is only part of the picture.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic oblique pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

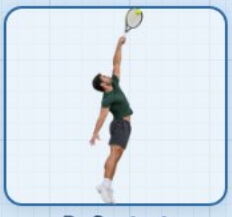
INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

TENNIS AND PADEL SHOULDER PAIN: SERVE MECHANICS AND LOAD MANAGEMENT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Trophy
Arm cocked



B · Contact
Full reach



C · Forehand
Racket over shoulder

When to change the plan



UK subacromial pain pathway; exercise first, injection benefit transient (<12 weeks), surgery not first-line. Pandey et al. (2025).

Decision pathway

1. **MONITOR**
   Measure racket-side total rotation against the other side through the season.
2. **LOAD**
   Plan weekly hitting and match density; matches carry the higher injury rate in padel.
3. **REHAB**
   Treat persisting cuff pain with exercise first; refer if no better by 12 weeks.

NOT RECOMMENDED

Repeated steroid injections; surgery as first-line care.

SEEK ASSESSMENT IF

A suspected fracture or dislocation after a fall, signs of infection, a lump, several inflamed joints, a child or adolescent, or no improvement after 12 weeks.

REFERENCES (APA 7)

Dahmen, J., Emanuel, K. S., Fontanellas-Fes, A., Verhagen, E., Kerkhoffs, G. M. M. J., & Pluim, B. M. (2023). Incidence, prevalence and nature of injuries in padel: A systematic review. *BMJ Open Sport & Exercise Medicine, 9*(2), e001607. https://doi.org/10.1136/bmjsem-2023-001607

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Ellenbecker, T. S., Roetert, E. P., Bailie, D. S., Davies, G. J., & Brown, S. W. (2002). Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Medicine and Science in Sports and Exercise, 34*(12), 2052–2056. https://doi.org/10.1097/00005768-200212000-00028

Maquirriain, J., Ghisi, J. P., & Amato, S. (2006). Is tennis a predisposing factor for degenerative shoulder disease? A controlled study in former elite players. *British Journal of Sports Medicine, 40*(5), 447–450. https://doi.org/10.1136/bjsm.2005.023382

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

VOLLEYBALL AND OVERHEAD-SPORT SHOULDER PAIN: SPIKING, BLOCKING AND RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

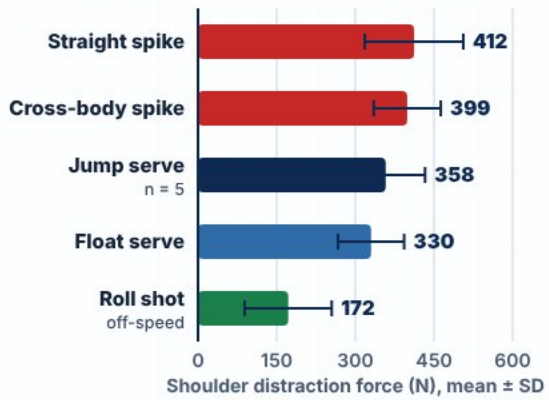
A · SPIKE COCKING, SIDE



Spike cocking: winding up in the air

- Airborne with the hitting arm cocked back, the shoulder is wound into external rotation before a fast internal-rotation swing at the ball.
- In English first-division men, spiking was the action at first onset in 23 of 29 shoulder injuries; cuff tendinitis was the commonest diagnosis.

The full spike pulls hardest on the joint



14 female collegiate players, 3-D motion capture. Reeser et al. (2010). Onset data: Wang & Cochrane (2001).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic airborne pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

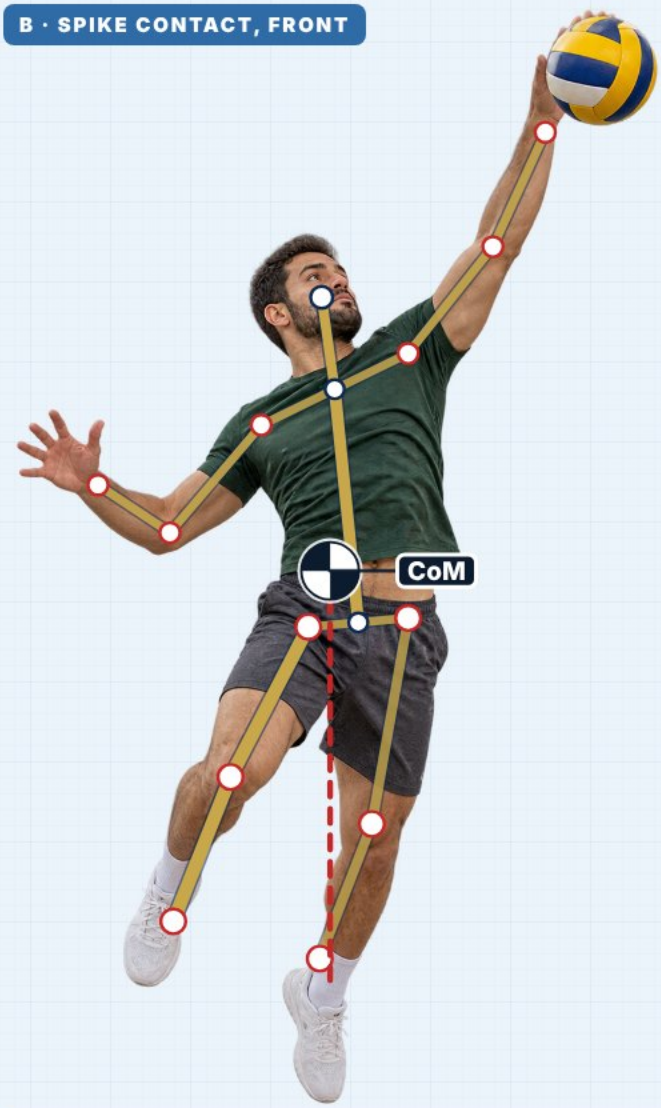
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

VOLLEYBALL AND OVERHEAD-SPORT SHOULDER PAIN: SPIKING, BLOCKING AND RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

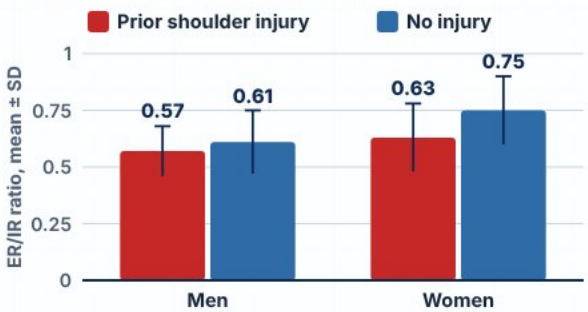
B · SPIKE CONTACT, FRONT



Contact: the arm is high and fast

- At contact the hitting arm is extended high, at about 130° of abduction in every skill measured; the cuff must then brake a very fast arm.
- The hitting arm gains internal-rotation strength without matching external-rotation gains; previously injured players had the lowest ratios.

External-rotator strength lags



183 elite players, isokinetic 60°/s, dominant side. Hadzic et al. (2014). Contact angle: Reeser et al. (2010).

Key point: among uninjured players, about 37% of men and 56% of women had external-rotation asymmetry above 15%.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic airborne pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

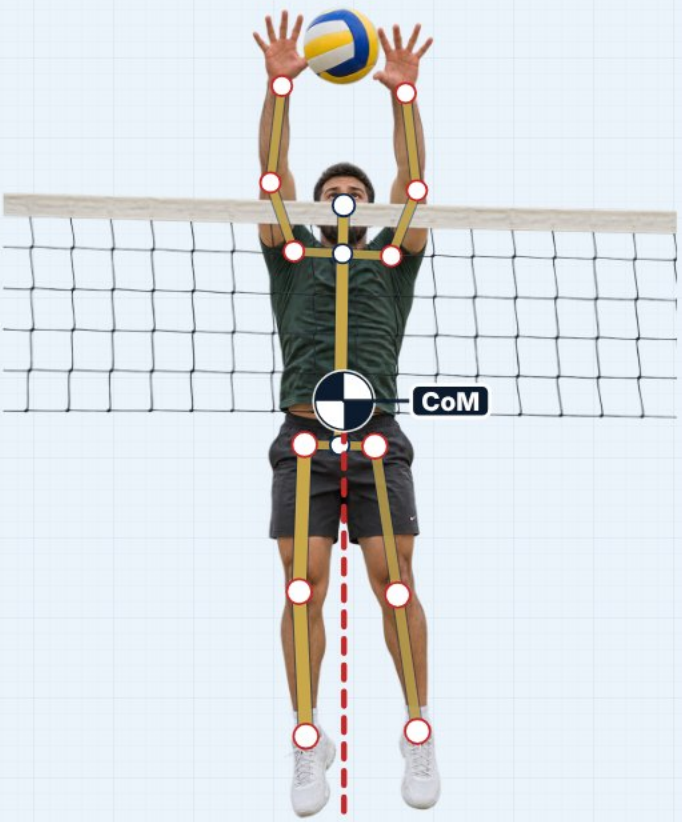
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

VOLLEYBALL AND OVERHEAD-SPORT SHOULDER PAIN: SPIKING, BLOCKING AND RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

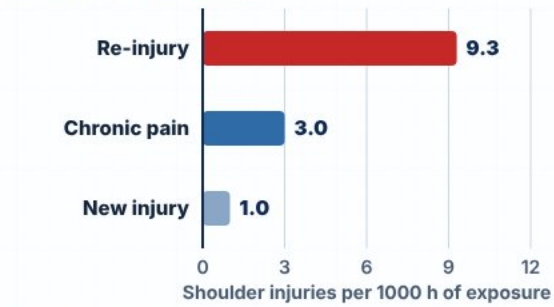
C · BLOCK AT THE NET, FRONT



Blocking and the risk of coming back

- Blocking holds both arms overhead but without the fast swing of the spike, so it is a lower-velocity overhead task.
- A previous shoulder injury was the biggest risk: re-injury incidence was about nine times the new-injury rate.

Re-injury dominates



59 English first-division men over two seasons; chronic pain lasted a mean of 2.3 months. Wang & Cochrane (2001).

Myth: "A sore hitter must stop all overhead play." Skills differ widely in load, so play can often continue with graded skill choice.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic airborne pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

VOLLEYBALL AND OVERHEAD-SPORT SHOULDER PAIN: SPIKING, BLOCKING AND RECOVERY

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Cocking
Arm wound back

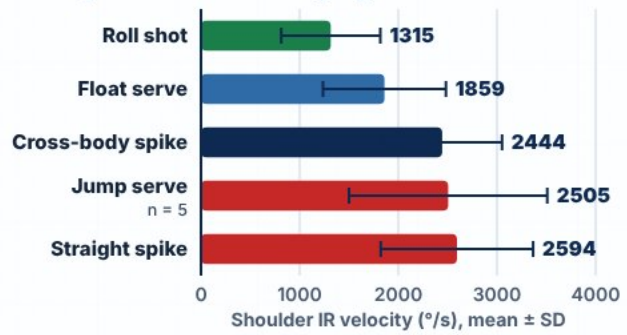


B · Contact
Arm high and fast



C · Block
Lower velocity

A ready-made return-to-play ladder



Same 14 players; jump serve not tested statistically. Reeser et al. (2010).

Decision pathway

1. **SKILL**
   Swap spikes for roll shots and jump serves for float serves while symptoms settle.
2. **STRENGTH**
   Build external-rotator strength to restore the external-to-internal rotation balance.
3. **RETURN**
   Finish rehabilitation before full spiking volume; refer if no better by 12 weeks.

NOT RECOMMENDED

Returning to full spiking volume before rehabilitation is complete; repeated steroid injections.

SEEK ASSESSMENT IF

A fall or contact with a suspected dislocation or fracture, signs of infection, a lump, several inflamed joints, or a child or adolescent with ongoing pain.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hadzic, V., Sattler, T., Veselko, M., Markovic, G., & Dervisevic, E. (2014). Strength asymmetry of the shoulders in elite volleyball players. *Journal of Athletic Training, 49*(3), 338–344. https://doi.org/10.4085/1062-6050-49.2.05

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Reeser, J. C., Fleisig, G. S., Bolt, B., & Ruan, M. (2010). Upper limb biomechanics during the volleyball serve and spike. *Sports Health, 2*(5), 368–374. https://doi.org/10.1177/1941738110374624

Wang, H. K., & Cochrane, T. (2001). A descriptive epidemiological study of shoulder injury in top level English male volleyball players. *International Journal of Sports Medicine, 22*(2), 159–163. https://doi.org/10.1055/s-2001-11346

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

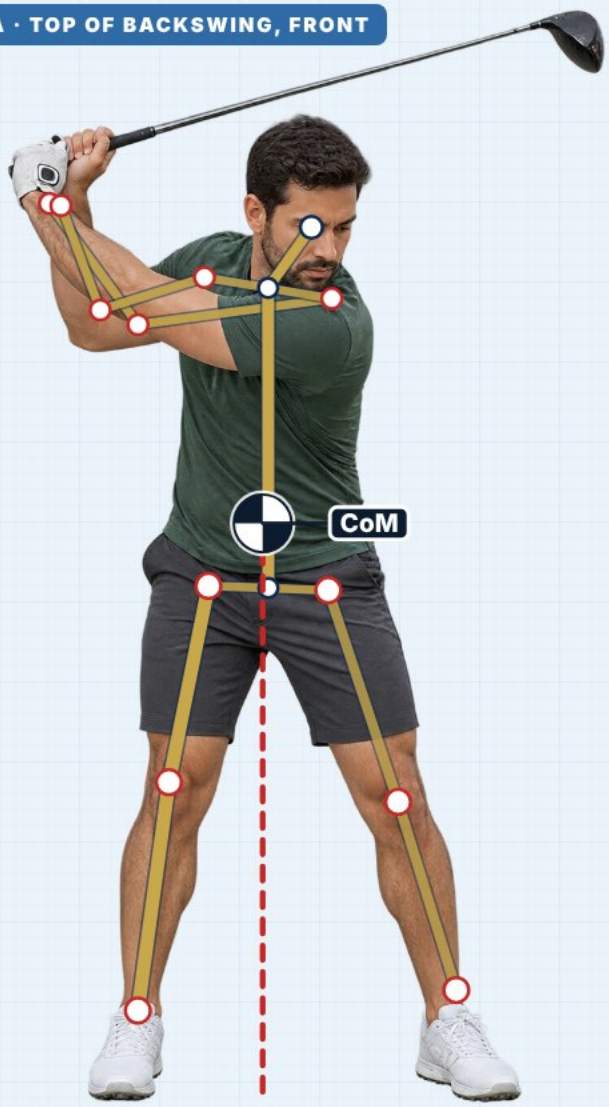
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

GOLF AND SHOULDER PAIN: THE LEAD SHOULDER AND SWING LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

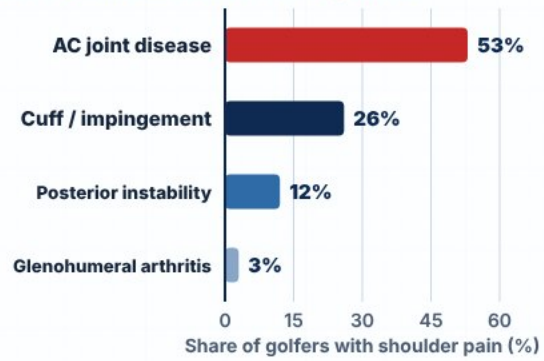
A · TOP OF BACKSWING, FRONT



Top of the backswing: the lead arm

- At the top, the lead arm is held across the chest in maximal cross-body adduction, a position that compresses the AC joint.
- More than 90% of shoulder problems in golfers involve the lead shoulder (the left in a right-handed player).

The AC joint leads in skilled golfers



35 professional or low-handicap golfers (Mallon & Colosimo); secondary figures from Kim et al. (2004).

Key point: a shorter backswing reduces cross-body adduction; this is expert advice for AC-type pain, not trial evidence.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic rotating pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

GOLF AND SHOULDER PAIN: THE LEAD SHOULDER AND SWING LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

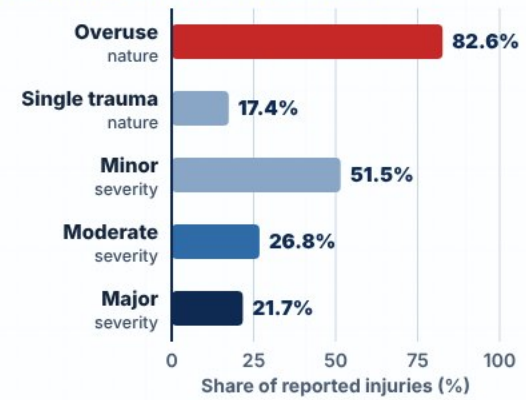
B · IMPACT, FRONT



Impact: speed, repeated

- Through impact the arms and club move rapidly while the trunk unwinds; each swing is modest, but the number of swings adds up.
- Carrying one's own bag was hazardous to the shoulder; warming up for at least 10 minutes had a positive effect.

Golf injuries are mostly overuse



703 professional and amateur golfers over two seasons. Gosheger et al. (2003).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic rotating pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

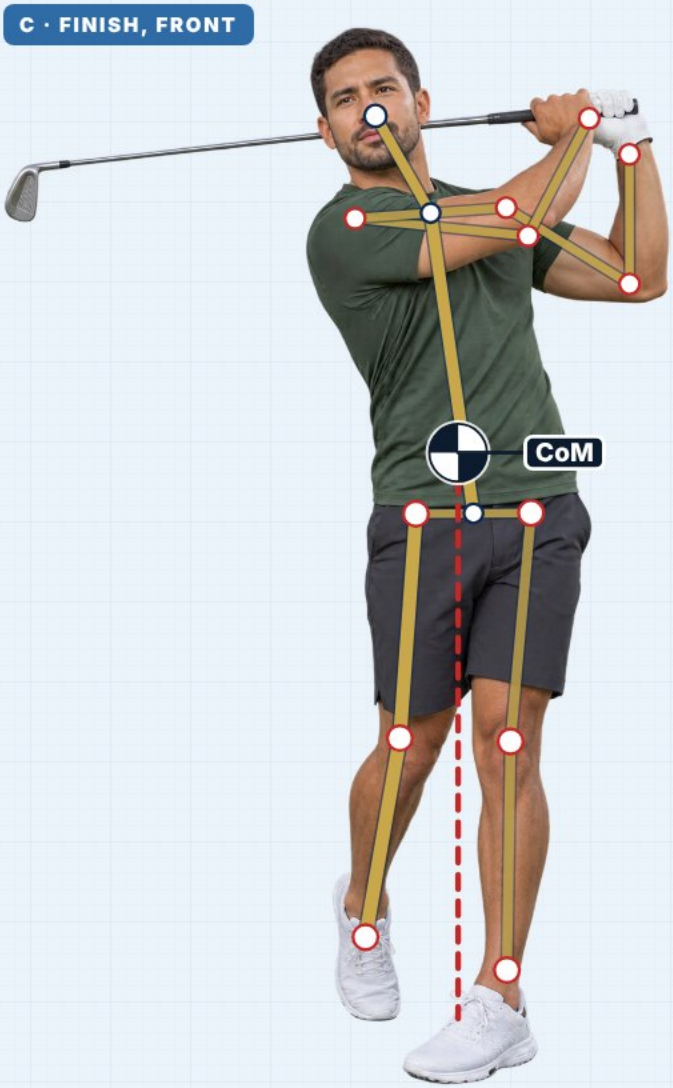
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

GOLF AND SHOULDER PAIN: THE LEAD SHOULDER AND SWING LOAD

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

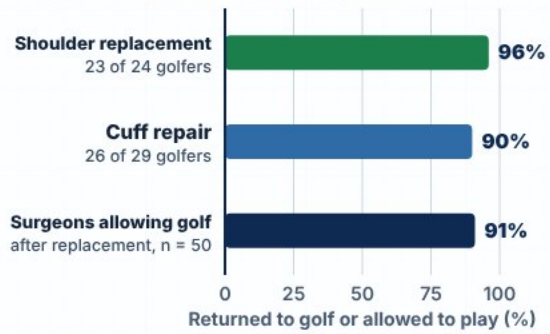
C · FINISH, FRONT



Finish: the chest faces the target

- At the finish both arms swing up past the head and the trail arm crosses the body as the swing decelerates.
- Most golfers return even after major shoulder surgery, typically at 4–5 months; replacement patients resumed at a mean of 4.5 months.

Most golfers get back to the game



Secondary figures from Kim et al. (2004); percentages computed from the counts given.

Myth: "Golf is gentle, so golf shoulder pain can't be serious." 82.6% of injuries were overuse and 21.7% were rated major.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Dynamic rotating pose: skeleton and whole-body CoM only; no joint angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

GOLF AND SHOULDER PAIN: THE LEAD SHOULDER AND SWING LOAD

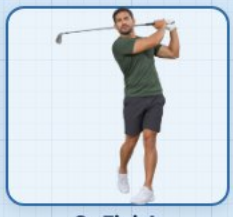
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Backswing
Lead arm across chest



B · Impact
Fast arm and club



C · Finish
Arms decelerate

When to change the plan



UK subacromial pain pathway; exercise first, injection benefit transient (<12 weeks), surgery not first-line. Pandey et al. (2025).

Decision pathway

1. **WARM UP**
   Warm up for at least 10 minutes and use a trolley rather than carrying the bag.
2. **GRADE**
   Build up by club length and swing size: putting, chipping, irons, then woods and a full round.
3. **REHAB**
   Treat persisting cuff or AC pain with exercise first; refer if no better by 12 weeks.

NOT RECOMMENDED

Repeated steroid injections; surgery as first-line care.

SEEK ASSESSMENT IF

New weakness lifting the arm in an older golfer, a suspected fracture or dislocation, signs of infection, a lump or several inflamed joints.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Gosheger, G., Liem, D., Ludwig, K., Greshake, O., & Winkelmann, W. (2003). Injuries and overuse syndromes in golf. *American Journal of Sports Medicine, 31*(3), 438–443. https://doi.org/10.1177/03635465030310031901

Kim, D. H., Millett, P. J., Warner, J. J. P., & Jobe, F. W. (2004). Shoulder injuries in golf. *American Journal of Sports Medicine, 32*(5), 1324–1330. https://doi.org/10.1177/0363546504267346

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

DESK WORK AND SHOULDER PAIN: REACH, MOUSE POSITION AND MOVEMENT BREAKS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

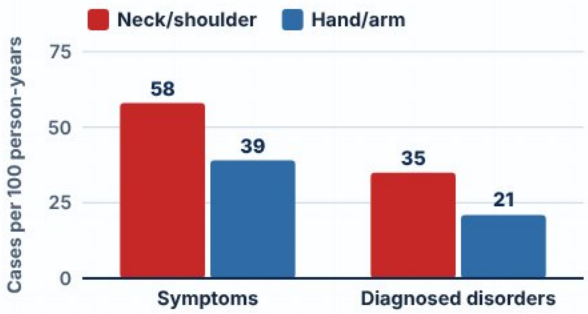
A · LONG MOUSE REACH, SIDE



Reaching far for the mouse

- Arm reached forward to **66°**: the arm's centre of mass sits ≈**28 cm** in front of the joint, ≈**10 N·m** if unsupported, held for hours.
- Moving the mouse to a central position cut upper-arm external rotation by nearly 40°; a keyboard without a number pad roughly halved shoulder flexion and abduction.

Neck and shoulder lead in new desk workers



632 new computer users (≥15 h/week), followed up to 3 years. Gerr et al. (2002). Mouse data: Dennerlein & Johnson (2006).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Hand resting on the mouse takes part of this load. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

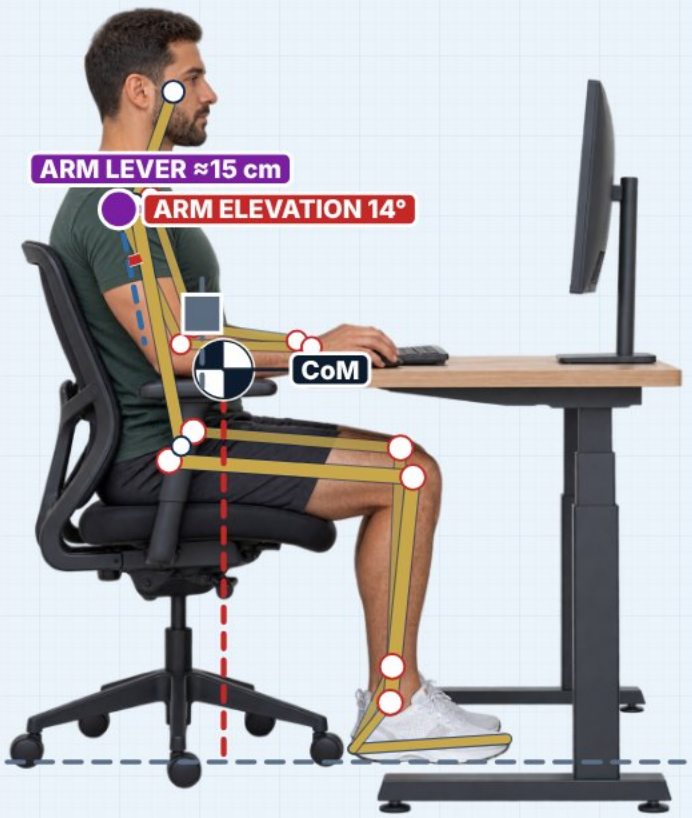
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

DESK WORK AND SHOULDER PAIN: REACH, MOUSE POSITION AND MOVEMENT BREAKS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

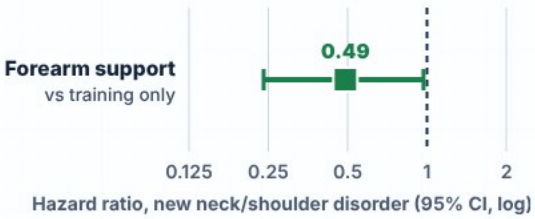
B · MOUSE CLOSE, SIDE



Mouse close, forearm supported

- Elbow by the side, arm at **14°**: the arm lever falls to **≈15 cm** (**≈5 N·m**), and the supported forearm carries part of that.
- In a one-year trial, adding a forearm support roughly halved the hazard of a new neck/shoulder disorder and reduced neck/shoulder pain.

Forearm support: a randomised trial



182 call-centre operators, blinded diagnosis; cost recovered in a predicted 10.6 months. Rempel et al. (2006).

Key point: of the desk set-up changes in this evidence, forearm support has the strongest trial support.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Forearm support not subtracted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

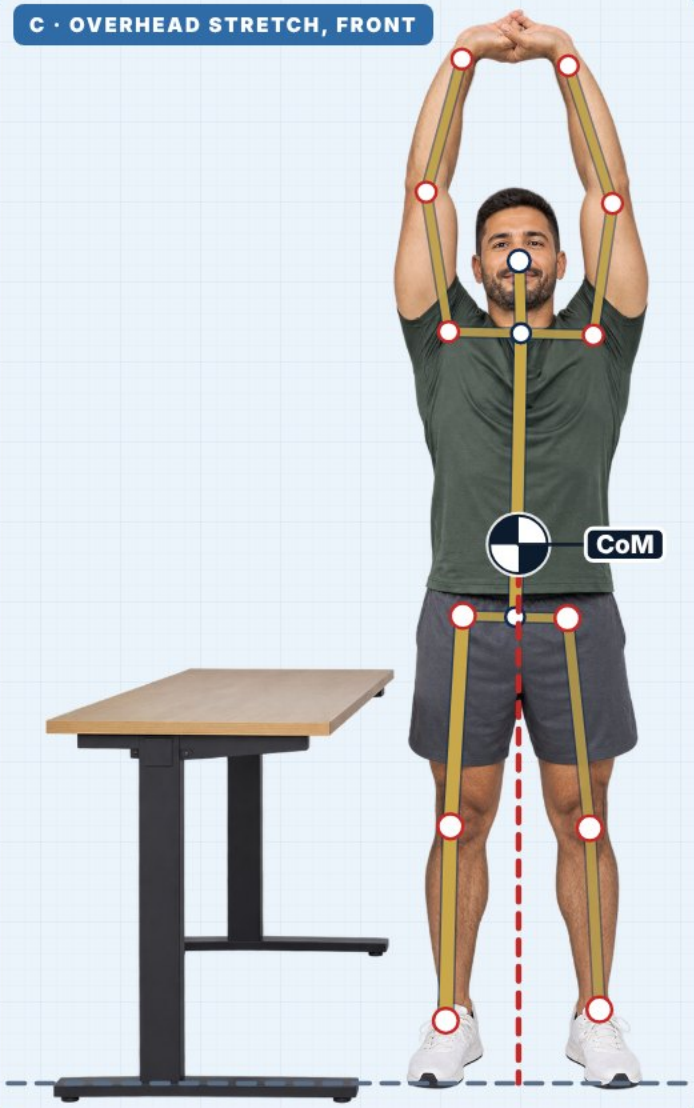
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

DESK WORK AND SHOULDER PAIN: REACH, MOUSE POSITION AND MOVEMENT BREAKS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

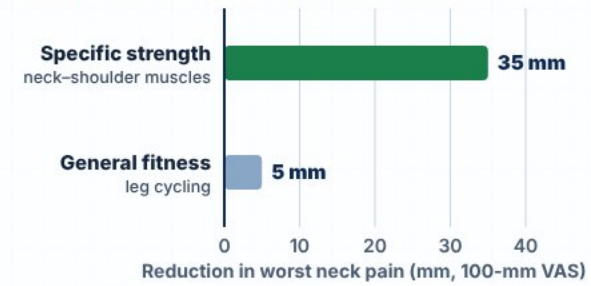
C · OVERHEAD STRETCH, FRONT



Breaks that load the shoulder

- Standing up with both arms stretched overhead: a simple break from hours of low-level static load at the keyboard.
- Specific neck–shoulder strength training cut worst pain by about 79%; general fitness gave only a small, brief effect.

Strength training beats general fitness



48 women with trapezius myalgia, 10-week randomised trial. Andersen et al. (2008).

Myth: "Any slouch damages the shoulder." Evidence linking computer work to shoulder tendonitis is insufficient; support and movement matter more than a perfect posture.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton and CoM only in this frame; no angles are quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

DESK WORK AND SHOULDER PAIN: REACH, MOUSE POSITION AND MOVEMENT BREAKS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Long reach
Lever ≈28 cm

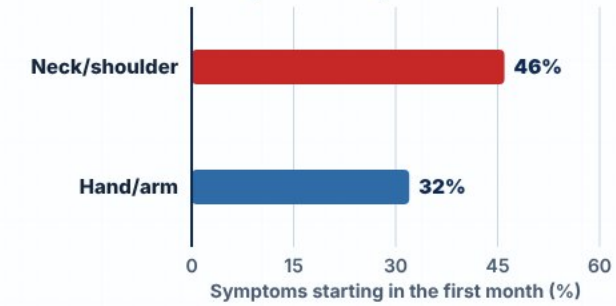


B · Mouse close
Lever ≈15 cm



C · Stretch break
Arms overhead

Problems start early in a new job



Same 632 new computer users. Gerr et al. (2002). Shoulder tendonitis evidence: Wærsted et al. (2010).

Decision pathway

1. **SUPPORT**
   Give the forearms support with armrests or a forearm board.
2. **MOUSE**
   Keep the mouse close and central, e.g. with a keyboard without a number pad.
3. **MOVE**
   Add specific neck–shoulder strength work; refer shoulder pain not better by 12 weeks.

NOT RECOMMENDED

Labelling desk-related aching as tendon damage.

SEEK ASSESSMENT IF

Arm pain with numbness, tingling or weakness; shoulder pain with chest pain, breathlessness or sweating (urgent); injury, infection or a lump.

REFERENCES (APA 7)

Andersen, L. L., Kjaer, M., Søgaard, K., Hansen, L., Kryger, A. I., & Sjøgaard, G. (2008). Effect of two contrasting types of physical exercise on chronic neck muscle pain. *Arthritis and Rheumatism, 59*(1), 84–91. https://doi.org/10.1002/art.23256

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Dennerlein, J. T., & Johnson, P. W. (2006). Changes in upper extremity biomechanics across different mouse positions in a computer workstation. *Ergonomics, 49*(14), 1456–1469. https://doi.org/10.1080/00140130600811620

Gerr, F., Marcus, M., Ensor, C., Kleinbaum, D., Cohen, S., Edwards, A., Gentry, E., Ortiz, D. J., & Monteilh, C. (2002). A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. *American Journal of Industrial Medicine, 41*(4), 221–235. https://doi.org/10.1002/ajim.10066

Pandey, R. A., Singh, H. P., & BESS Subacromial Pain Working Group. (2025). BESS patient care pathway: Subacromial pain. *Shoulder & Elbow, 17*(6), 713–724. https://doi.org/10.1177/17585732251374282

Rempel, D. M., Krause, N., Goldberg, R., Benner, D., Hudes, M., & Goldner, G. U. (2006). A randomised controlled trial evaluating the effects of two workstation interventions on upper body pain and incident musculoskeletal disorders among computer operators. *Occupational and Environmental Medicine, 63*(5), 300–306.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Wærsted, M., Hanvold, T. N., & Veiersted, K. B. (2010). Computer work and musculoskeletal disorders of the neck and upper extremity: A systematic review. *BMC Musculoskeletal Disorders, 11*, 79. https://doi.org/10.1186/1471-2474-11-79

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

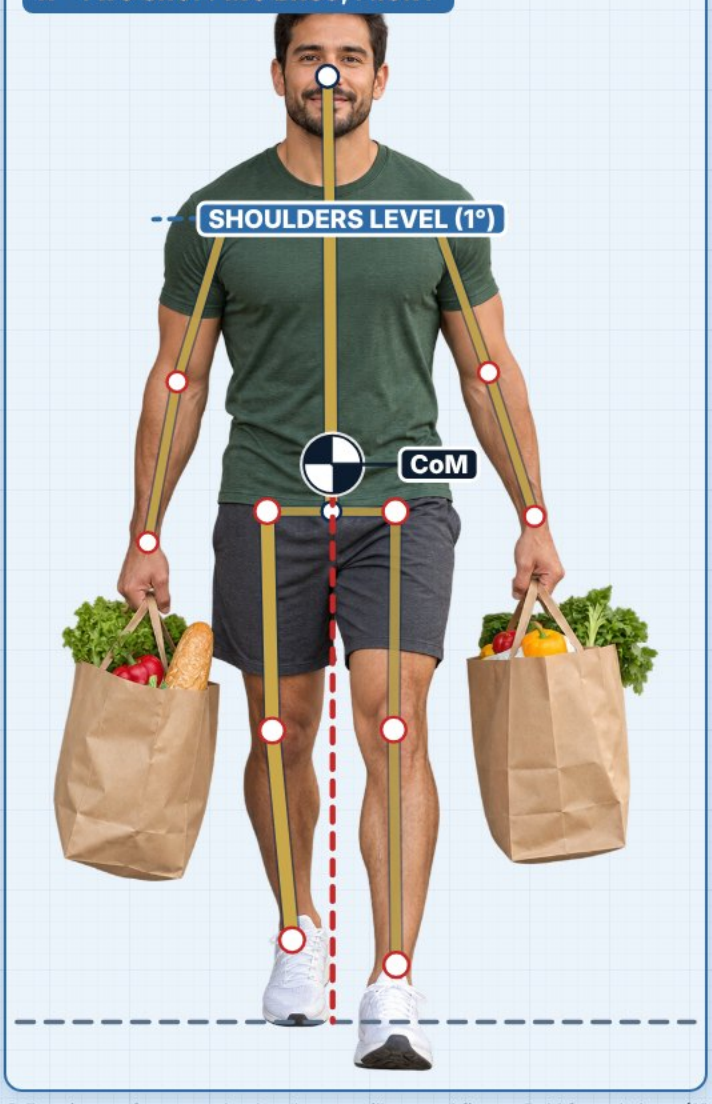
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CARRYING BAGS AND CHILDREN: EVERYDAY SHOULDER LOADS THAT ADD UP

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

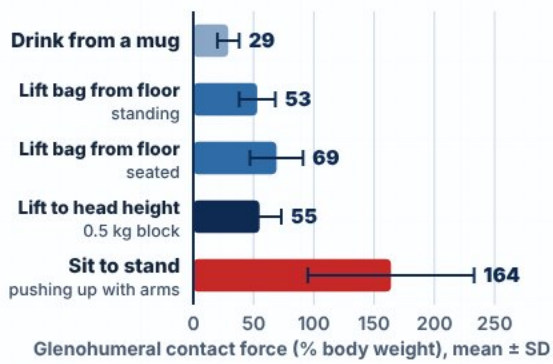
A · TWO SHOPPING BAGS, FRONT



Two bags: split the load

- With a bag in each hand the shoulders stay level (**1°**) and each load hangs almost directly under its joint, so the lever on the shoulder is small.
- Lifting a shopping bag from the floor was modelled at about half of body weight through the joint, similar to lifting a light block to head height.

Everyday lifting loads the joint



25 adults, 26 daily tasks; musculoskeletal model estimates, not implant data. 10 of 26 tasks exceeded 50% BW. Klemt et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

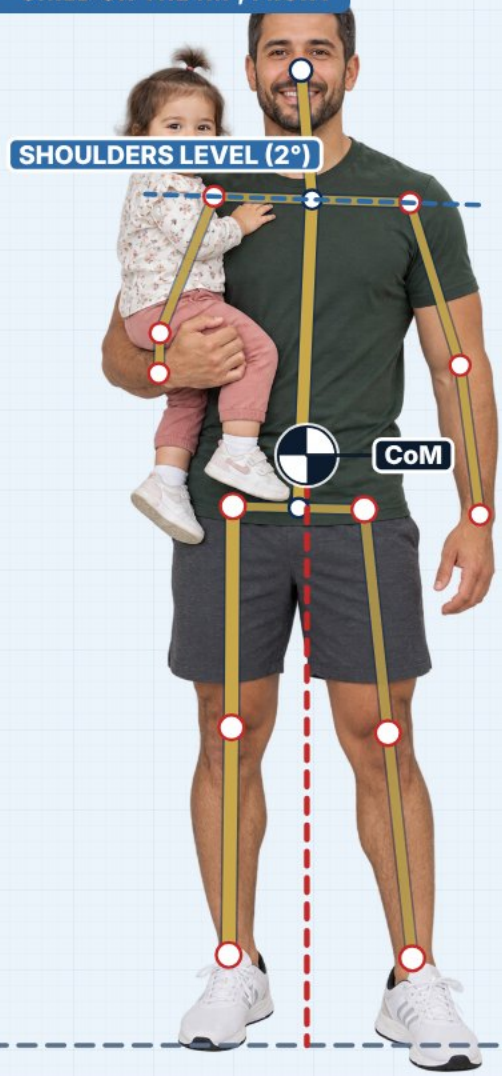
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CARRYING BAGS AND CHILDREN: EVERYDAY SHOULDER LOADS THAT ADD UP

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

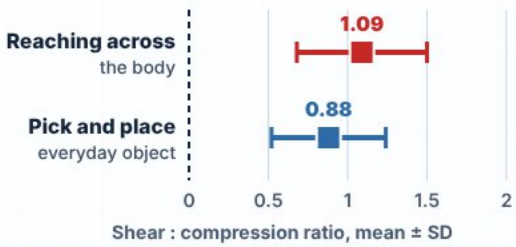
B · CHILD ON THE HIP, FRONT



Close to the trunk is kinder

- Child supported on the hip, shoulders level (**2°**): the weight rests on the pelvis and the arm mainly steadies it, rather than holding it out at arm's length.
- Reaching and placing objects away from the body raise shear relative to compression; the ratio exceeded 0.5 in 8 of 26 daily tasks.

Reaching away adds shear



Same 25 adults; higher ratios mean a less centred joint load. Klemt et al. (2018).

Myth: "Carrying damages the shoulder, so avoid it." The links are with heavy, frequent, prolonged work exposure, and they are associations, not proof of cause.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CARRYING BAGS AND CHILDREN: EVERYDAY SHOULDER LOADS THAT ADD UP

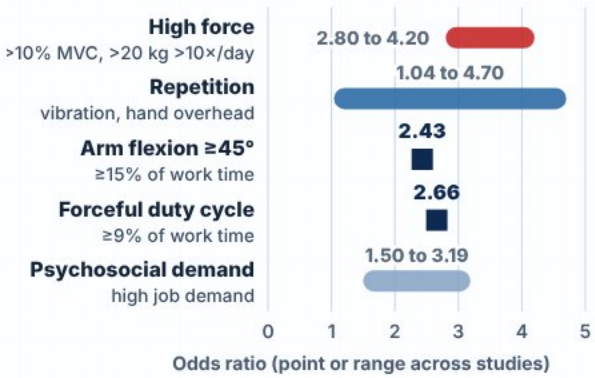
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Dose is what adds up

- Lifting the basket with the trunk **12°** forward and the arm at **26°**: knees and hips share the work and the load stays close, keeping the shoulder lever short.
- In workers, impingement was associated with heavy, frequent and prolonged force exposure, with psychosocial demand alongside physical load.

Work exposures linked with impingement



Systematic review of cross-sectional and cohort studies; associations, not causes. van Rijn et al. (2010).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from hip–shoulder line vs vertical; arm elevation from trunk line to upper arm. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

CARRYING BAGS AND CHILDREN: EVERYDAY SHOULDER LOADS THAT ADD UP

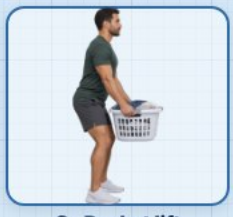
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Two bags
Load split, level

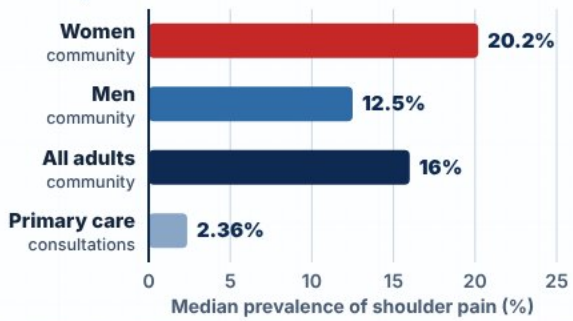


B · Child on hip
Weight on the pelvis



C · Basket lift
Trunk 12°, load close

Shoulder pain is common



61 studies worldwide; community median 16% (range 0.67–55.2%). Lucas et al. (2022).

Decision pathway

1. **SPLIT**
   Share loads between both hands and switch the hip that carries a child.
2. **CLOSE**
   Keep loads near the trunk and lift from the floor with the legs, not at arm's length.
3. **DOSE**
   Grade how heavy, how often and how long you carry; practise the real tasks in rehabilitation.

NOT RECOMMENDED

Avoiding carrying altogether, or repeated heavy floor lifts held away from the body.

SEEK ASSESSMENT IF

Pain after a fall with inability to lift the arm, a hot swollen joint with fever, or shoulder pain with chest pain or breathlessness.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Lafrance, S., Charron, M., Roy, J.-S., Dyer, J.-O., Frémont, P., Dionne, C. E., MacDermid, J. C., Tousignant, M., Rochette, A., Doiron-Cadrin, P., Lowry, V., Bureau, N., Lamontagne, M., Sandman, E., Coutu, M.-F., Lavigne, P., & Desmeules, F. (2022). Diagnosing, managing, and supporting return to work of adults with rotator cuff disorders: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 52*(10), 647–664. https://doi.org/10.2519/jospt.2022.11306

Lucas, J., van Doorn, P., Hegedus, E., Lewis, J., & van der Windt, D. (2022). A systematic review of the global prevalence and incidence of shoulder pain. *BMC Musculoskeletal Disorders, 23*, 1073. https://doi.org/10.1186/s12891-022-05973-8

van Rijn, R. M., Huisstede, B. M. A., Koes, B. W., & Burdorf, A. (2010). Associations between work-related factors and specific disorders of the shoulder: A systematic review of the literature. *Scandinavian Journal of Work, Environment & Health, 36*(3), 189–201. https://doi.org/10.5271/sjweh.2895

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

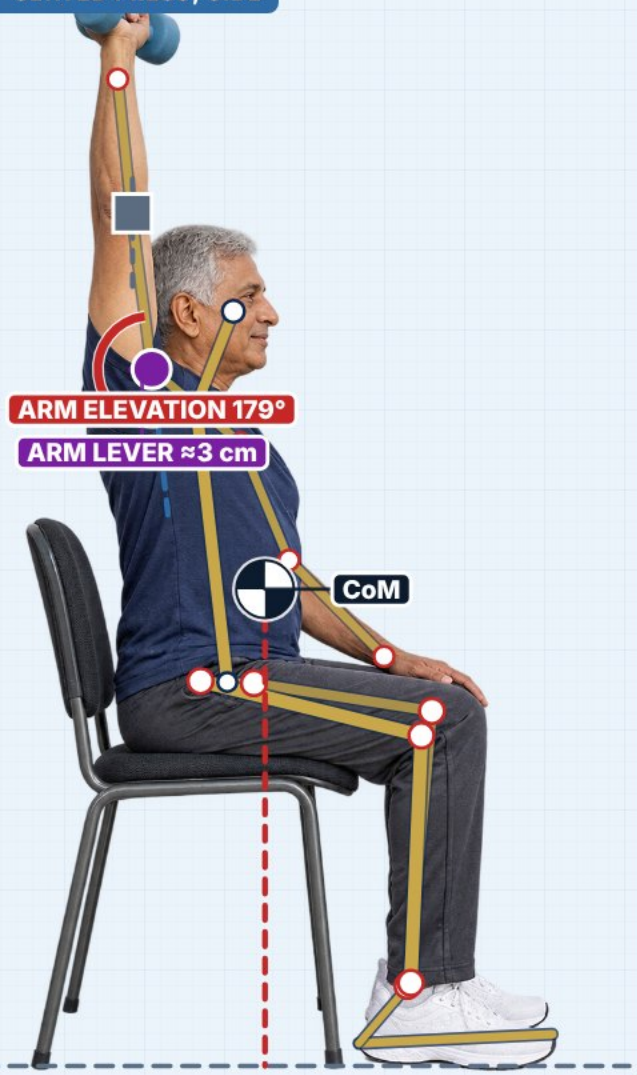
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AFTER 60: STRENGTH, CUFF HEALTH AND INDEPENDENCE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

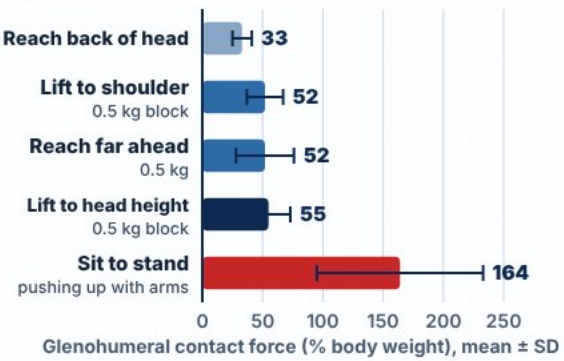
A · SEATED PRESS, SIDE



Overhead strength keeps you independent

- Seated press with the arm at **179°**: the arm is stacked over the joint (lever ≈**3 cm**), a low-load way to train overhead control.
- Pushing up from a chair with the arms was the heaviest common daily task modelled, so shoulder strength matters beyond reaching.

Daily tasks and joint load



25 adults, 26 daily tasks; musculoskeletal model estimates, not implant data. Klemt et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

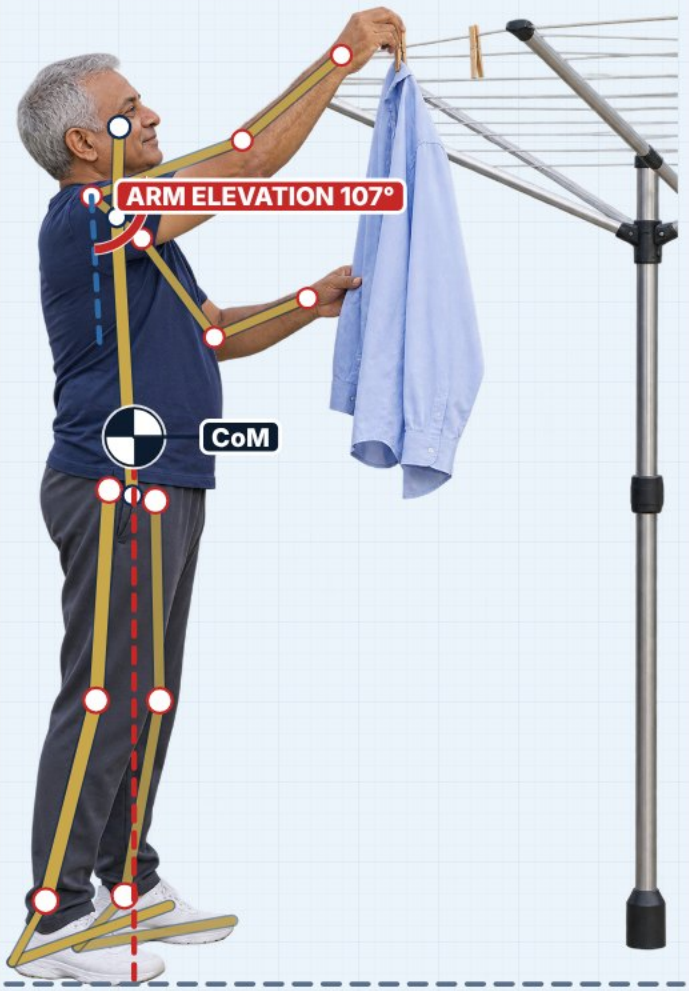
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AFTER 60: STRENGTH, CUFF HEALTH AND INDEPENDENCE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

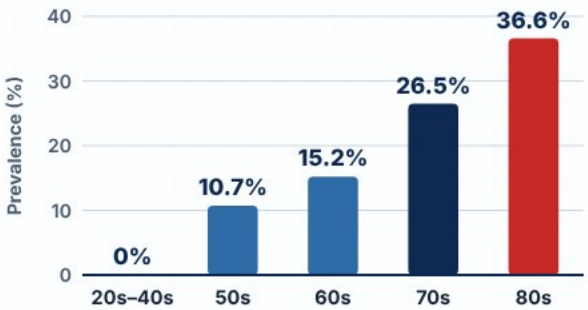
B · HANGING WASHING, SIDE



Cuff tears are common with age

- Hanging washing, arm at **107°**: the arm's weight acts ≈**29 cm** from the joint, ≈**10 N·m** held by the cuff and deltoid.
- In one village screening, full-thickness tears rose from none before 50 to over a third in the 80s.

Full-thickness cuff tears by age



664 residents screened by ultrasound; 22.1% had a tear. Minagawa et al. (2013).

Myth: "A tear on my scan means the shoulder is finished." Most tears found over 60 caused no symptoms.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AFTER 60: STRENGTH, CUFF HEALTH AND INDEPENDENCE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

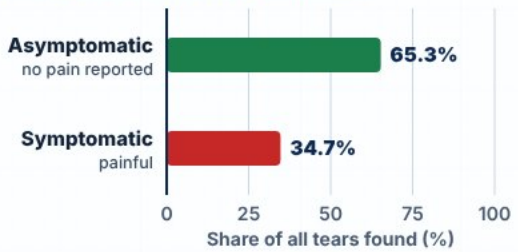
C · BAND PULL-APART, FRONT



A scan alone does not explain pain

- Band pull-apart with the shoulders level (**0°**): a light, controllable load for the cuff and shoulder-blade muscles that is easy to progress.
- Overall, 65% of tears found in screening were painless (about half in the 50s), so a tear on a scan may be incidental to the pain.

Most tears found were painless



147 people with full-thickness tears; about two-thirds of tears over 60 were painless. Minagawa et al. (2013).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN AFTER 60: STRENGTH, CUFF HEALTH AND INDEPENDENCE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Seated press
Lever ≈3 cm

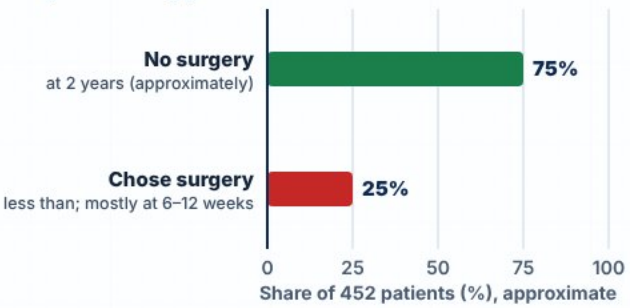


B · Washing line
≈10 N·m



C · Band pull-apart
Light, progressive

Physiotherapy for atraumatic tears



Prospective multicentre cohort, structured physiotherapy; outcomes improved at 6 and 12 weeks. Kuhn et al. (2013).

Decision pathway

1. **SCREEN**
   Ask about falls, sudden weakness and general health before starting exercise.
2. **STRENGTHEN**
   Progress cuff and shoulder-blade exercise by load and range, including overhead work.
3. **FUNCTION**
   Practise real tasks such as reaching shelves, hanging washing and rising from a chair.

NOT RECOMMENDED

Deciding on surgery from a scan alone; subacromial decompression for cuff tendinopathy.

SEEK ASSESSMENT IF

Sudden loss of arm lifting after a fall or jerk, deformity or bruising after a fall, new pain with chest symptoms, fever or weight loss.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Kuhn, J. E., Dunn, W. R., Sanders, R., An, Q., Baumgarten, K. M., Bishop, J. Y., Brophy, R. H., Carey, J. L., Holloway, B. G., Jones, G. L., Ma, C. B., Marx, R. G., McCarty, E. C., Poddar, S. K., Smith, M. V., Spencer, E. E., Vidal, A. F., Wolf, B. R., & Wright, R. W. (2013). Effectiveness of physical therapy in treating atraumatic full-thickness rotator cuff tears: A multicenter prospective cohort study. *Journal of Shoulder and Elbow Surgery, 22*(10), 1371–1379. https://doi.org/10.1016/j.jse.2013.01.026

Lafrance, S., Charron, M., Roy, J.-S., Dyer, J.-O., Frémont, P., Dionne, C. E., MacDermid, J. C., Tousignant, M., Rochette, A., Doiron-Cadrin, P., Lowry, V., Bureau, N., Lamontagne, M., Sandman, E., Coutu, M.-F., Lavigne, P., & Desmeules, F. (2022). Diagnosing, managing, and supporting return to work of adults with rotator cuff disorders: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 52*(10), 647–664. https://doi.org/10.2519/jospt.2022.11306

Minagawa, H., Yamamoto, N., Abe, H., Fukuda, M., Seki, N., Kikuchi, K., Kijima, H., & Itoi, E. (2013). Prevalence of symptomatic and asymptomatic rotator cuff tears in the general population: From mass-screening in one village. *Journal of Orthopaedics, 10*(1), 8–12. https://doi.org/10.1016/j.jor.2013.01.008

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN IN MENOPAUSE: FROZEN SHOULDER RISK AND STAYING ACTIVE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

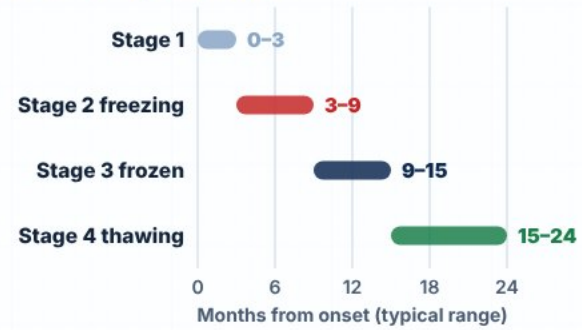
A · OVERHEAD REACH, FRONT



Frozen shoulder peaks in midlife

- Full overhead reach, arm at **160°** (lever **≈8 cm**): one of the first movements to shrink when the capsule thickens and tightens.
- Frozen shoulder affects 2–5.3% of people, most often between 40 and 65 and more often women, an age band that overlaps the menopause.

A slow, staged course



Guideline synthesis; mild pain and stiffness may remain at 12–18 months, and recovery may be slower with diabetes. Kelley et al. (2013).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

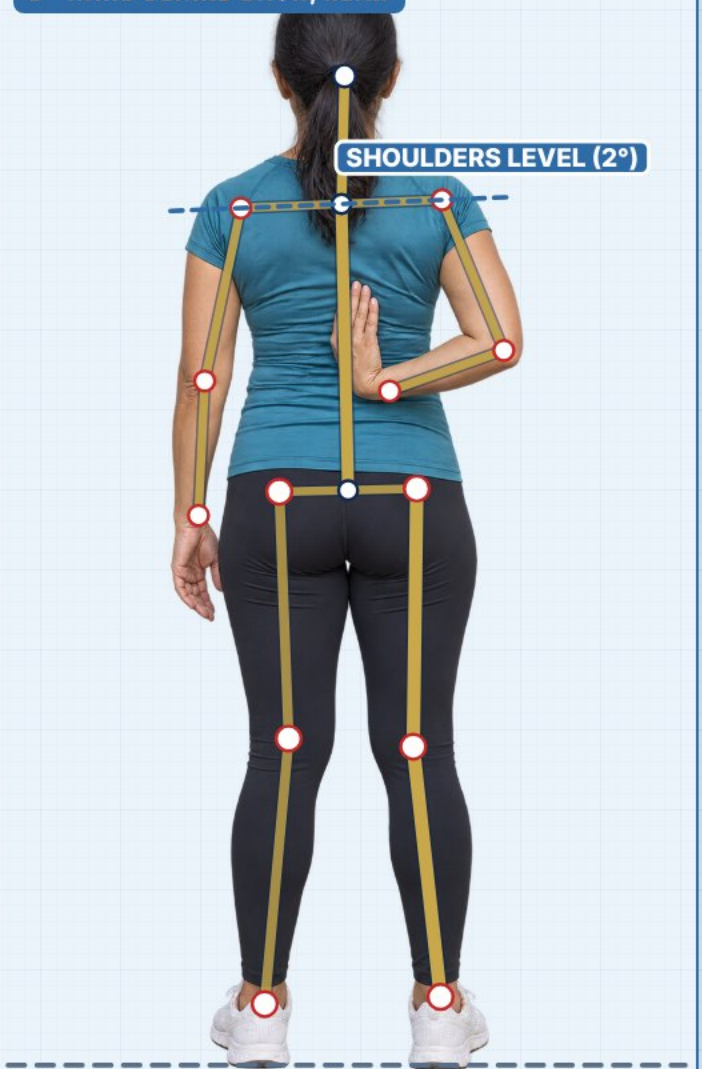
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN IN MENOPAUSE: FROZEN SHOULDER RISK AND STAYING ACTIVE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

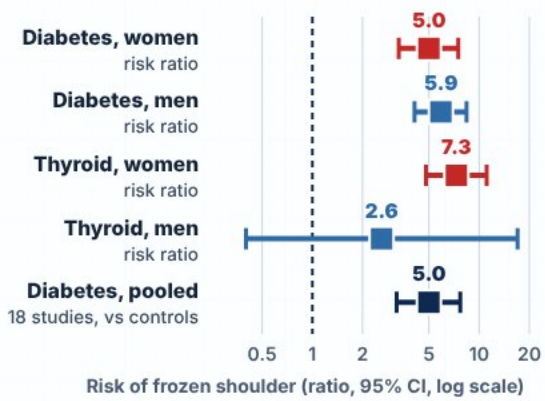
B · HAND BEHIND BACK, REAR



Screen for diabetes and thyroid disease

- Hand behind the back, shoulders level (**2°**): reaching up the back needs internal rotation, often lost early alongside external rotation.
- Diabetes and thyroid disease are better documented risk markers than menopause itself; 30% of people with frozen shoulder had diabetes.

Metabolic risk markers



Risk ratios: Milgrom et al., cited in Kelley et al. (2013). Pooled likelihood and 30% (24–37%): Zreik et al. (2016).

Myth: "Rest the stiff shoulder until it thaws." The guideline recommends education and stretching matched to how irritable the shoulder is.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the rear view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

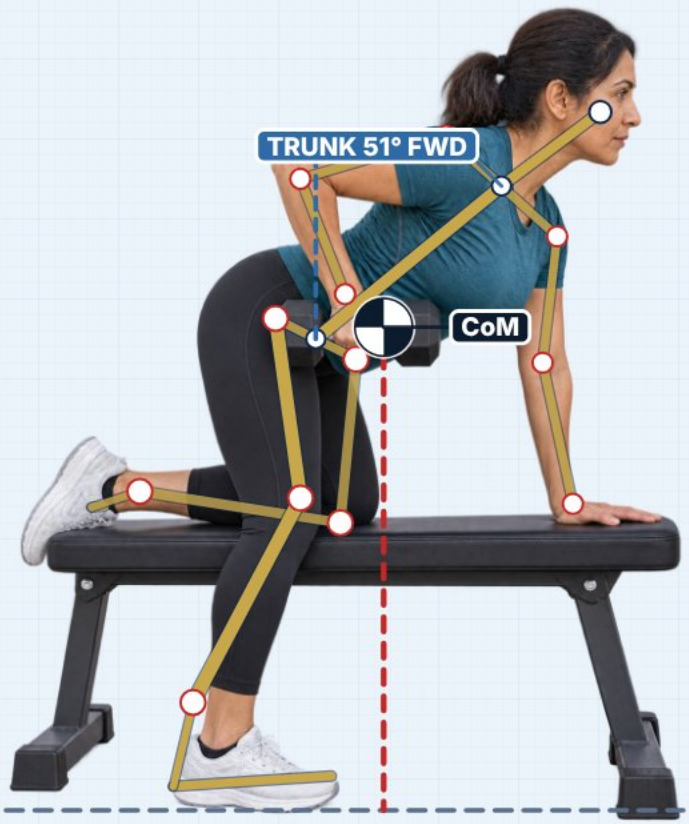
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN IN MENOPAUSE: FROZEN SHOULDER RISK AND STAYING ACTIVE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

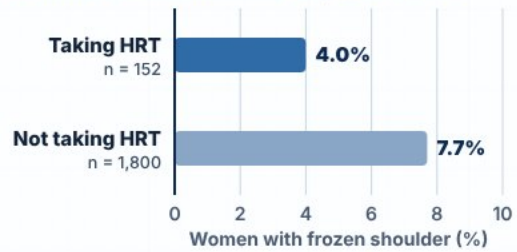
C · ONE-ARM ROW, SIDE



Hormone therapy: not significant

- One-arm row with the trunk **51°** from vertical and supported on the bench: strength work for the back and cuff can continue while range recovers.
- In women aged 45–60, the lower rate with HRT was **not statistically significant** (OR 1.99, 95% CI 0.86–4.58, p = 0.11).

HRT and frozen shoulder, ages 45–60



1,952 women, one US centre, retrospective conference abstract; diabetes also differed between groups. Saltzman et al. (2023).

Key point: HRT should not be presented as frozen-shoulder prevention; discuss it only for its established indications.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from hip–shoulder line vs vertical in the side view. Educational, not diagnostic.

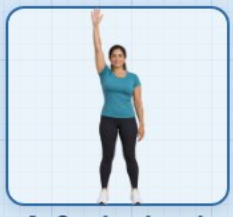
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER PAIN IN MENOPAUSE: FROZEN SHOULDER RISK AND STAYING ACTIVE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Overhead reach
Arm 160°

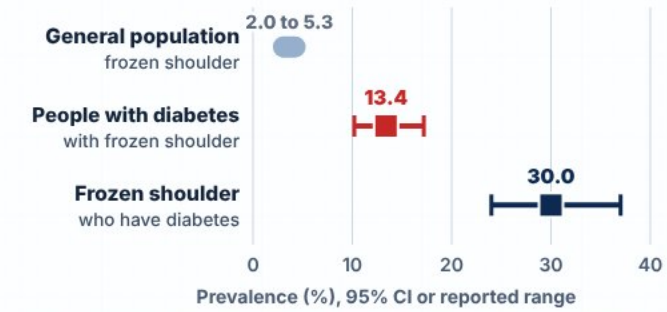


B · Behind back
Internal rotation



C · One-arm row
Keep strength

Diabetes and frozen shoulder



Meta-analysis of 18 studies: Zreik et al. (2016). General-population range: Kelley et al. (2013).

Decision pathway

1. **EXPLAIN**
   Describe the natural course of 1–2 years (Grade B) and check for diabetes and thyroid disease.
2. **STRETCH**
   Stretch within tolerable pain, matched to irritability (Grade B); keep the rest of the body strong.
3. **RELIEVE**
   A corticosteroid injection eases pain and function for 4–6 weeks (Grade A); mobilisation may help (Grade C).

NOT RECOMMENDED

Prolonged rest of the stiff shoulder; presenting HRT as prevention.

SEEK ASSESSMENT IF

Signs of infection or tumour, fever, or findings that do not fit or do not resolve; arthritis on X-ray points to another diagnosis.

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Kelley, M. J., Shaffer, M. A., Kuhn, J. E., Michener, L. A., Seitz, A. L., Uhl, T. L., Godges, J. J., & McClure, P. W. (2013). Shoulder pain and mobility deficits: Adhesive capsulitis. Clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy, 43*(5), A1–A31. https://doi.org/10.2519/jospt.2013.0302

Saltzman, E., Kennedy, J., Ford, A., Reinke, E., Green, C., Poehlein, E., & Wittstein, J. (2023). Poster 188: Is hormone replacing therapy associated with reduced risk of adhesive capsulitis in menopausal women? A single center analysis [Conference abstract]. Orthopaedic Journal of Sports Medicine, 11(7 Suppl. 3), 2325967123S00174. https://doi.org/10.1177/2325967123S00174

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Zreik, N. H., Malik, R. A., & Charalambous, C. P. (2016). Adhesive capsulitis of the shoulder and diabetes: A meta-analysis of prevalence. *Muscles, Ligaments and Tendons Journal, 6*(1), 26–34. https://doi.org/10.11138/mltj/2016.6.1.026

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

EXTERNAL ROTATION STRENGTH: WHY THE CUFF'S WEAKEST DIRECTION MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

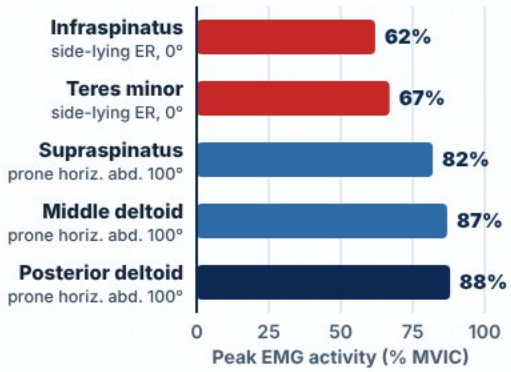
A · SIDE-LYING ER, FRONT



Side-lying ER targets the posterior cuff

- Lying on the side with a towel under the elbow, the dumbbell is turned against gravity with the arm at the side, so the load falls on the external rotators.
- Of seven ER exercises tested, this one gave the highest infraspinatus and teres minor activity.

Best exercise for each muscle



10 healthy adults, intramuscular electrodes; each bar is the exercise giving that muscle's peak. Reinold et al. (2004).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Skeleton only: angles are not quoted for lying poses. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

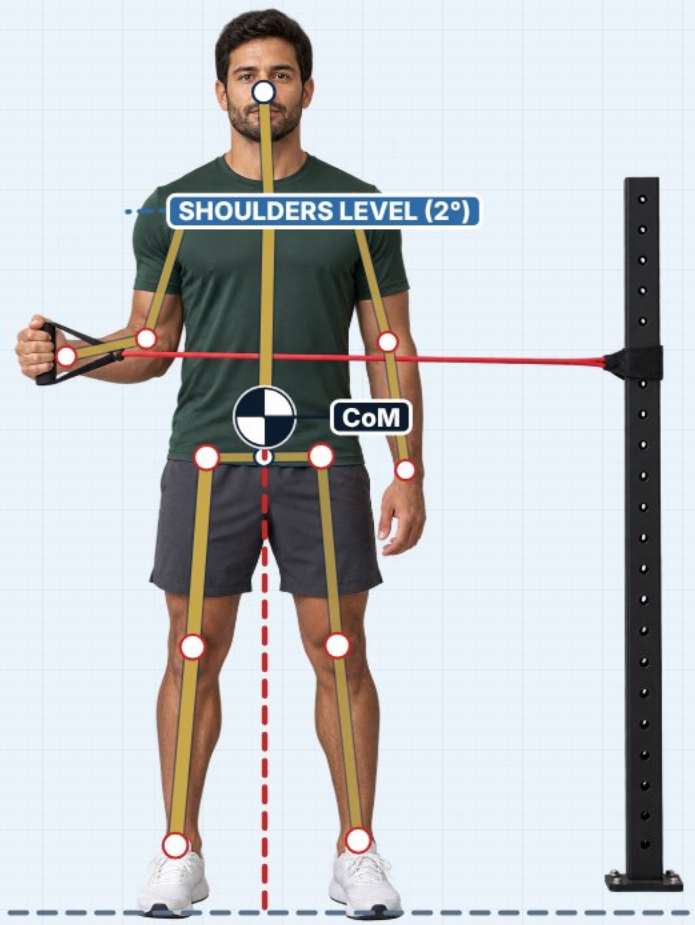
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

EXTERNAL ROTATION STRENGTH: WHY THE CUFF'S WEAKEST DIRECTION MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

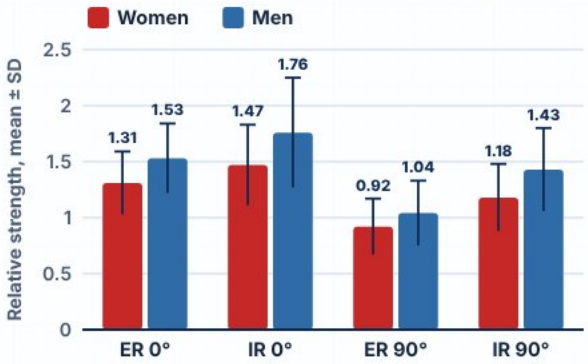
B · BAND ER AT SIDE, FRONT



ER is the weaker rotation

- Band ER with the elbow at the side, shoulders level (**2°**): the low-elevation position where most ER programmes start.
- In 400 healthy adults ER was weaker than IR at the side and at 90° abduction, and both rotations were weaker at 90°.

Isometric rotation strength, dominant arm



Body-weight-normalised units from the source (relative values, not newtons); handheld dynamometer, ages 20–59. Bradley & Pierpoint (2023).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

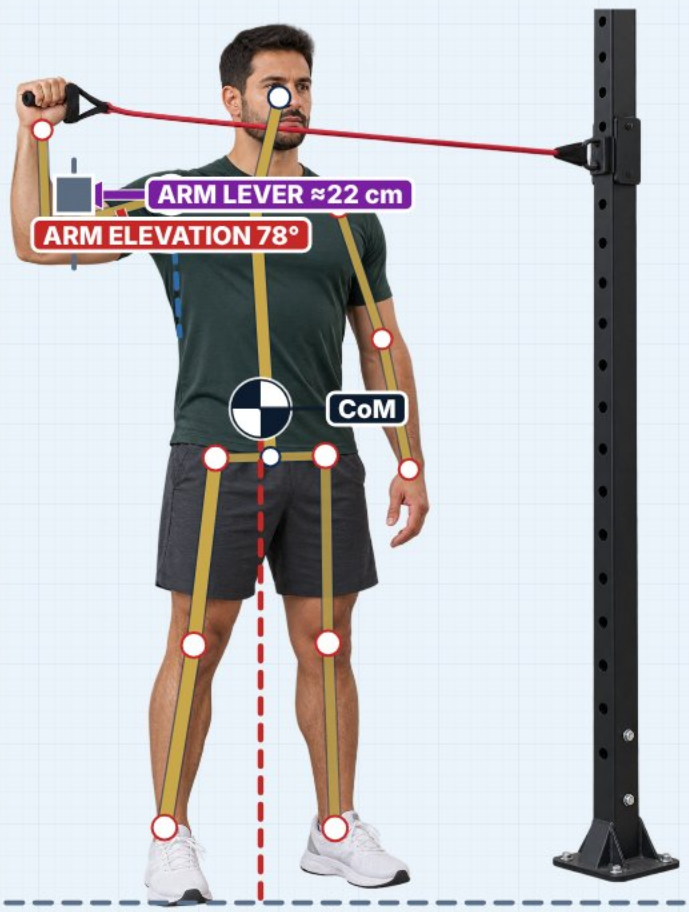
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

EXTERNAL ROTATION STRENGTH: WHY THE CUFF'S WEAKEST DIRECTION MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

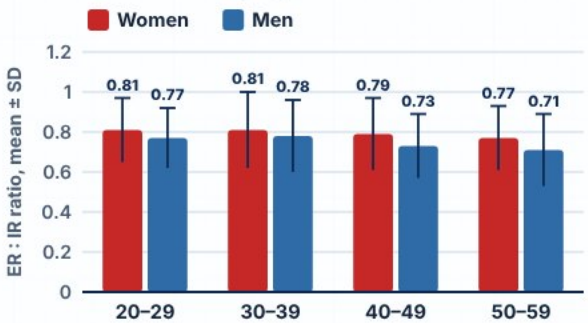
C · BAND ER AT 90°, FRONT



At 90° the lever gets longer

- Arm raised to **78°** in this view: the arm's weight now acts **≈22 cm** from the joint (**≈7 N·m**) while the cuff also rotates against the band.
- In healthy adults ER at 90° was roughly three-quarters of IR, slightly lower in older age bands.

ER:IR ratio at 90° by age



Same 400 healthy adults, dominant arm, 90° abduction. Bradley & Pierpoint (2023).

Myth: "ER below IR means something is wrong." Ratios of 0.71–0.81 are normal in healthy adults.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

EXTERNAL ROTATION STRENGTH: WHY THE CUFF'S WEAKEST DIRECTION MATTERS

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Side-lying ER
Peak posterior cuff

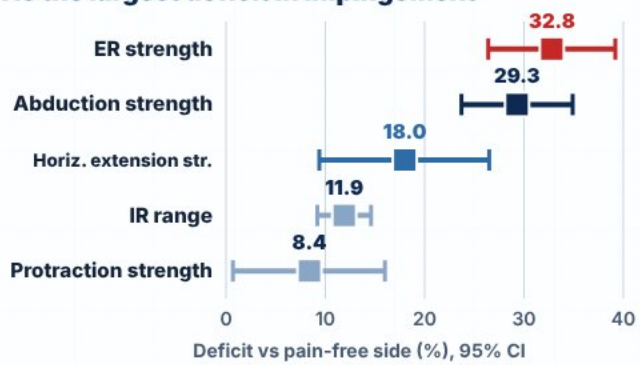


B · ER at side
Start position



C · ER at 90°
Lever ≈22 cm

ER is the largest deficit in impingement



87 patients with a pain-free opposite shoulder; abduction range deficit 29.5%. Pain, not strength, explained SPADI. Clausen et al. (2017).

Decision pathway

1. **MEASURE**
   Test ER strength directly, e.g. a handheld dynamometer against the other side.
2. **LOAD**
   Start side-lying or at the side, then progress towards 90° as part of active rehabilitation.
3. **RECHECK**
   Retest strength; an improving questionnaire score does not prove strength has returned.

NOT RECOMMENDED

Subacromial decompression for cuff tendinopathy; judging strength from symptoms alone.

SEEK ASSESSMENT IF

Sudden loss of the ability to lift or rotate the arm after a fall or forceful pull, especially with marked weakness.

REFERENCES (APA 7)

Bradley, H., & Pierpoint, L. (2023). Normative values of isometric shoulder strength among healthy adults. *International Journal of Sports Physical Therapy, 18*(4), 977–988. https://doi.org/10.26603/001c.83938

Clausen, M. B., Witten, A., Holm, K., Christensen, K. B., Attrup, M. L., Hölmich, P., & Thorborg, K. (2017). Glenohumeral and scapulothoracic strength impairments exists in patients with subacromial impingement, but these are not reflected in the shoulder pain and disability index. *BMC Musculoskeletal Disorders, 18*, 302. https://doi.org/10.1186/s12891-017-1667-1

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Lafrance, S., Charron, M., Roy, J.-S., Dyer, J.-O., Frémont, P., Dionne, C. E., MacDermid, J. C., Tousignant, M., Rochette, A., Doiron-Cadrin, P., Lowry, V., Bureau, N., Lamontagne, M., Sandman, E., Coutu, M.-F., Lavigne, P., & Desmeules, F. (2022). Diagnosing, managing, and supporting return to work of adults with rotator cuff disorders: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 52*(10), 647–664. https://doi.org/10.2519/jospt.2022.11306

Reinold, M. M., Wilk, K. E., Fleisig, G. S., Zheng, N., Barrentine, S. W., Chmielewski, T., Cody, R. C., Jameson, G. G., & Andrews, J. R. (2004). Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *Journal of Orthopaedic & Sports Physical Therapy, 34*(7), 385–394. https://doi.org/10.2519/jospt.2004.34.7.385

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

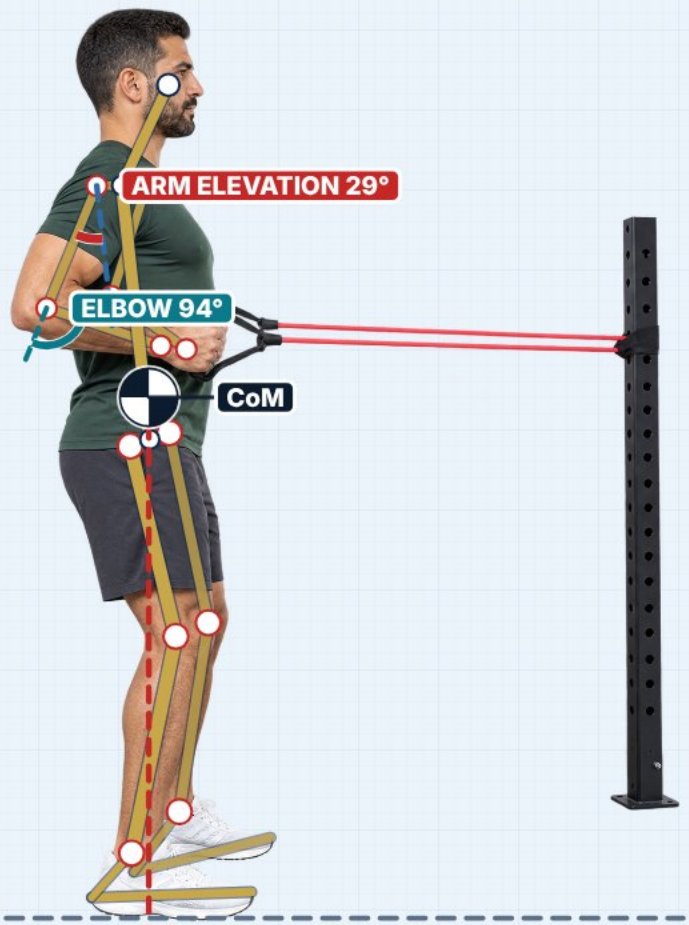
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SCAPULAR EXERCISES: WHO BENEFITS FROM SHOULDER BLADE TRAINING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

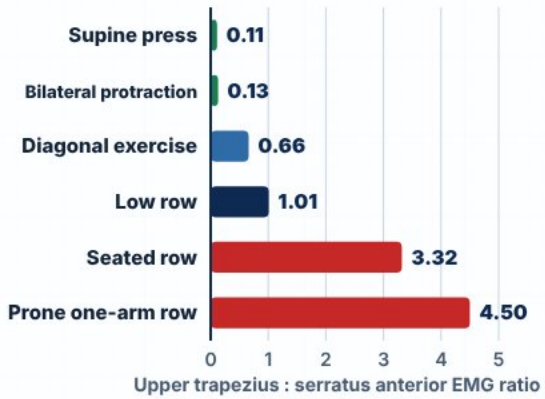
A · STANDING BAND ROW, SIDE



Rows train the retractors

- Band row with the elbow at **94°** and the upper arm **29°** from the trunk line as it drives back: the shoulder blades squeeze together.
- Rows do not bias serratus anterior; pressing and protraction tasks do. Ratios below 1 mean serratus works relatively more than upper trapezius.

Pressing favours serratus, rows do not



15 EMG studies in healthy shoulders, ratios compiled from Ekstrom and Cools. Schory et al. (2016).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation from trunk line to upper arm; elbow angle between upper arm and forearm. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SCAPULAR EXERCISES: WHO BENEFITS FROM SHOULDER BLADE TRAINING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

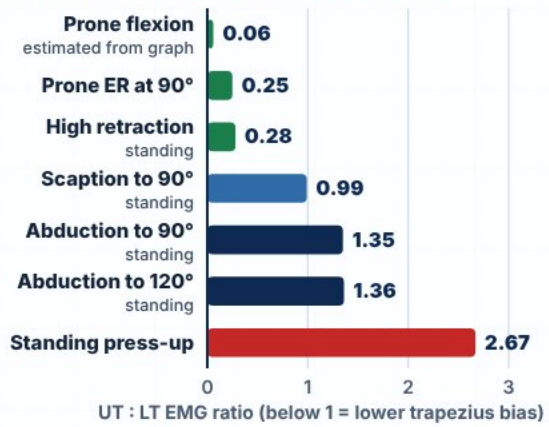
B · PRONE Y RAISE, REAR



Prone raises favour lower trapezius

- Chest-supported Y with the arms at about **120°** and the shoulders level (**0°**): the lower trapezius helps rotate the blade upward.
- Prone overhead raises and prone ER emphasise lower over upper trapezius; standing abduction tends to bias the upper trapezius.

Choosing a lower-trapezius exercise



15 observational EMG studies in normal shoulders. Schory et al. (2016).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation from trunk line to upper arm in the rear view; prone pose, angle approximate. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

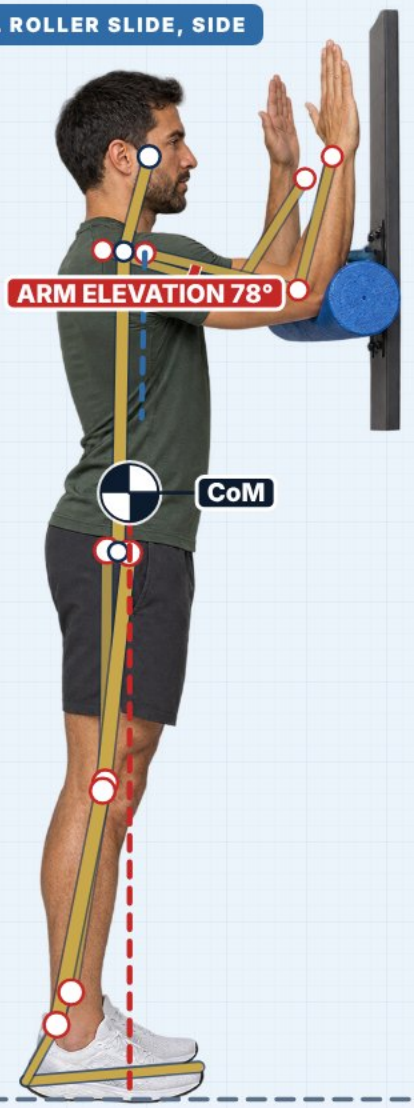
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SCAPULAR EXERCISES: WHO BENEFITS FROM SHOULDER BLADE TRAINING?

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

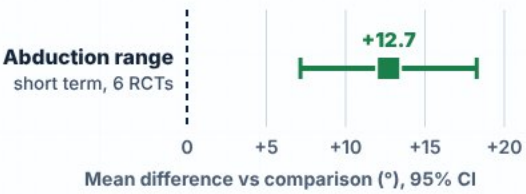
C · WALL ROLLER SLIDE, SIDE



Short-term gains, then they fade

- Wall roller slide, arm at **78°**: an upward-rotation task that biases serratus anterior with the arm supported.
- In subacromial pain, adding scapular work improved pain with activity (MD −0.88, 95% CI −1.19 to −0.58) and function short term, but not at follow-up.

Range gained with scapular-focused care



6 RCTs, adults with subacromial pain; heterogeneity I^2 36%. Saito et al. (2018).

Key point: scapular work belongs inside a broader progressive shoulder programme, not on its own.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm elevation from trunk line to upper arm; arm supported, so no lever is quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SCAPULAR EXERCISES: WHO BENEFITS FROM SHOULDER BLADE TRAINING?

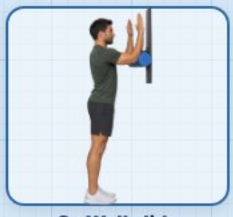
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Band row
Retractors

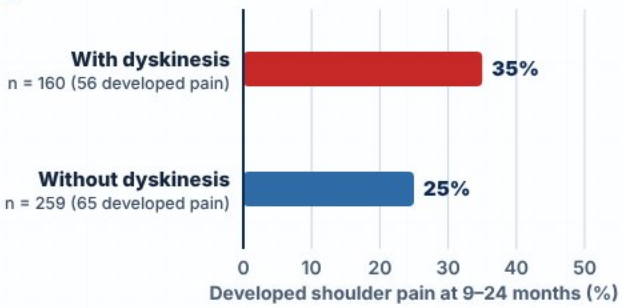


B · Prone Y
Lower trapezius



C · Wall slide
Serratus anterior

Dyskinesis is a modest risk marker



419 asymptomatic athletes, 5 prospective studies; RR 1.43 (95% CI 1.05–1.93). Hickey et al. (2018).

Decision pathway

1. **ASSESS**
   Look for a real scapular strength or control deficit, not just how the blade looks.
2. **SELECT**
   Lower-trapezius bias: prone Y, prone ER. Serratus bias: presses, protraction, wall slides.
3. **INTEGRATE**
   Add scapular work to progressive cuff and shoulder exercise with education.

NOT RECOMMENDED

Treating a visible change in shoulder blade movement alone as the cause of pain.

SEEK ASSESSMENT IF

Marked or sudden winging, especially with weakness after a neck or shoulder injury or a viral illness (possible nerve problem).

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Hickey, D., Solvig, V., Cavalheri, V., Harrold, M., & Mckenna, L. (2018). Scapular dyskinesis increases the risk of future shoulder pain by 43% in asymptomatic athletes: A systematic review and meta-analysis. *British Journal of Sports Medicine, 52*(2), 102–110. https://doi.org/10.1136/bjsports-2017-097559

Lafrance, S., Charron, M., Roy, J.-S., Dyer, J.-O., Frémont, P., Dionne, C. E., MacDermid, J. C., Tousignant, M., Rochette, A., Doiron-Cadrin, P., Lowry, V., Bureau, N., Lamontagne, M., Sandman, E., Coutu, M.-F., Lavigne, P., & Desmeules, F. (2022). Diagnosing, managing, and supporting return to work of adults with rotator cuff disorders: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 52*(10), 647–664. https://doi.org/10.2519/jospt.2022.11306

Saito, H., Harrold, M. E., Cavalheri, V., & McKenna, L. (2018). Scapular focused interventions to improve shoulder pain and function in adults with subacromial pain: A systematic review and meta-analysis. *Physiotherapy Theory and Practice, 34*(9), 653–670. https://doi.org/10.1080/09593985.2018.1423656

Schory, A., Bidinger, E., Wolf, J., & Murray, L. (2016). A systematic review of the exercises that produce optimal muscle ratios of the scapular stabilizers in normal shoulders. *International Journal of Sports Physical Therapy, 11*(3), 321–336. https://pmc.ncbi.nlm.nih.gov/articles/PMC4886800/

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

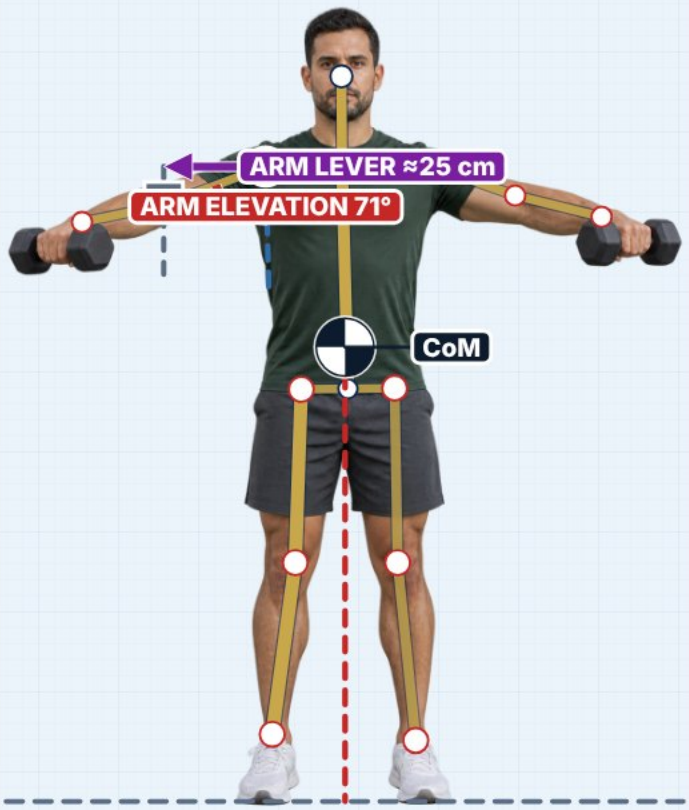
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN DURING SHOULDER REHABILITATION: WHEN TO MODIFY, PAUSE OR SEEK HELP

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

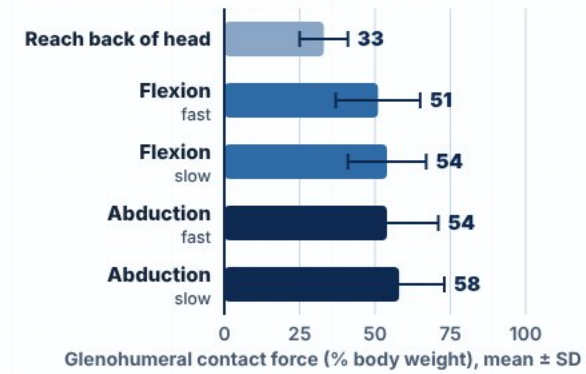
A · LATERAL RAISE, FRONT



Load, range and speed are the levers

- Lateral raise with the arm at **71°**: the arm's weight acts ≈**25 cm** from the joint (≈**8 N·m**) before the dumbbell is counted.
- Raising the arm unloaded already loads the joint at about half of body weight, so reduce load, range or speed when pain rises.

Unloaded arm raising and joint load



25 adults, musculoskeletal model of 26 daily tasks, not implant data. Klemt et al. (2018).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

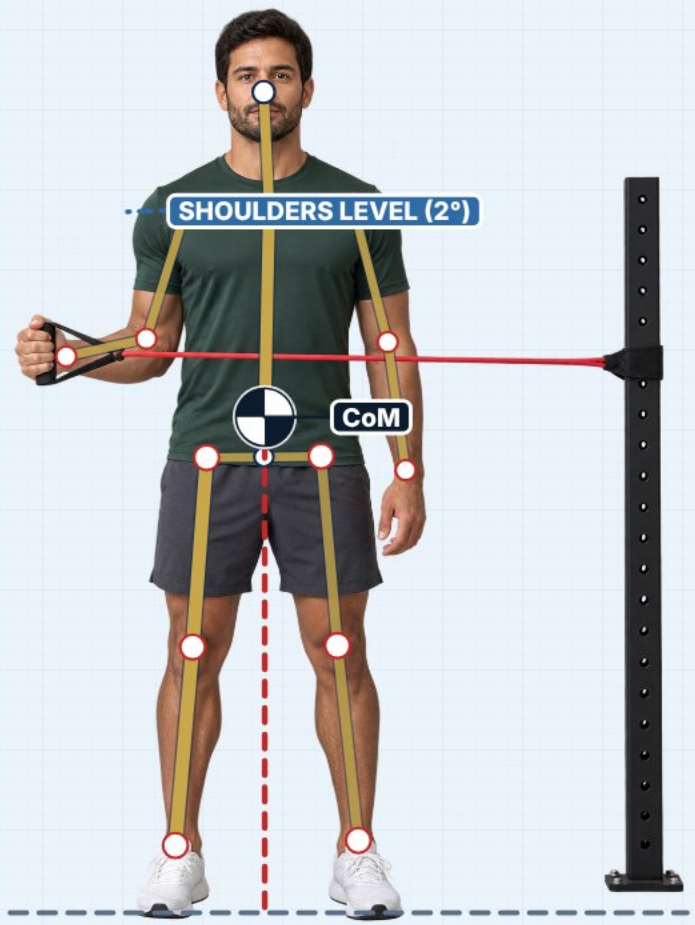
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN DURING SHOULDER REHABILITATION: WHEN TO MODIFY, PAUSE OR SEEK HELP

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

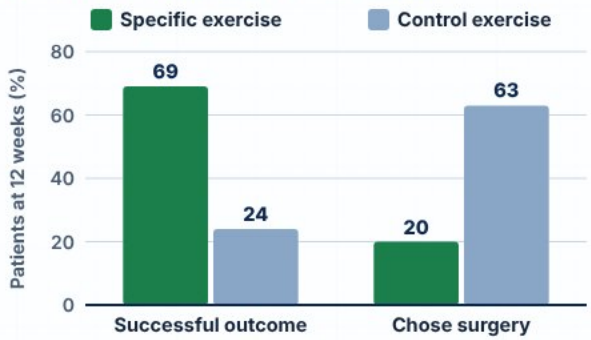
B · BAND ER AT SIDE, FRONT



A pain ceiling of 5 out of 10

- Band ER with the elbow at the side and shoulders level (**2°**): a cuff exercise that is easy to scale by band tension.
- In long-standing impingement, patients exercised with pain allowed up to 5/10; far fewer chose surgery than controls (20% vs 63%).

Specific cuff and scapular exercise



97 of 102 patients completed 12 weeks; surgery OR 7.7 (95% CI 3.1–19.4). Holmgren et al. (2012).

Myth: "If it hurts, stop: pain means damage." Exercising into pain up to 5/10 did better than controls.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN DURING SHOULDER REHABILITATION: WHEN TO MODIFY, PAUSE OR SEEK HELP

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

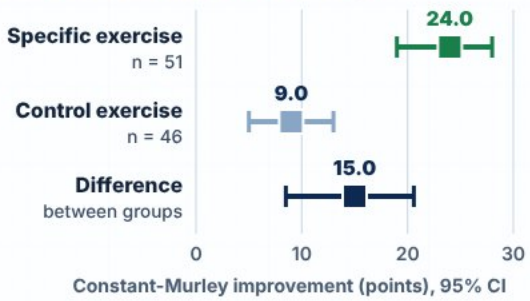
C · OVERHEAD PRESS, SIDE



Painful exercise is not harmful

- Overhead press at **147°** with the arm stacked over the joint (lever **≈4 cm**): if pain passes the ceiling, shorten the range or lighten the load first.
- Across chronic pain trials, painful exercise gave a small short-term pain benefit (SMD −0.27) and no difference later.

Shoulder score with a 5/10 ceiling



Holmgren et al. (2012). Painful vs pain-free: 7 RCTs, 385 people, SMD −0.27 (−0.54 to −0.05), Smith et al. (2017).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

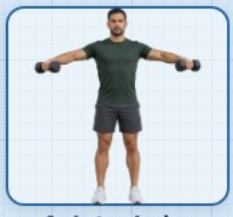
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

PAIN DURING SHOULDER REHABILITATION: WHEN TO MODIFY, PAUSE OR SEEK HELP

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Lateral raise
≈8 N·m arm only

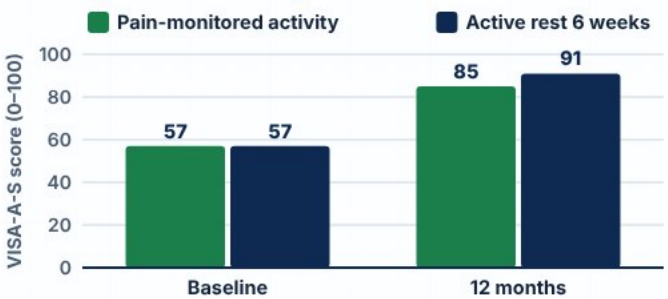


B · Band ER
Scale by tension



C · Overhead press
Shorten range

Where pain monitoring came from



Achilles tendinopathy, 38 patients (not shoulder data); difference not significant. Silbernagel et al. (2007).

Decision pathway

1. **CEILING**
   Agree an acceptable level, e.g. up to 5/10 during exercise, settling by the next day.
2. **MODIFY**
   Above the ceiling or worse next day: reduce load, range, speed or sets.
3. **PAUSE**
   Pause only the aggravating exercise; keep the rest of the programme going.

NOT RECOMMENDED

Insisting on completely pain-free exercise, or stopping all exercise at the first pain.

SEEK ASSESSMENT IF

Severe constant pain, waking every night, fever or a hot swollen joint, new arm weakness or numbness, chest symptoms, or a fall or "pop".

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Holmgren, T., Björnsson Hallgren, H., Öberg, B., Adolfsson, L., & Johansson, K. (2012). Effect of specific exercise strategy on need for surgery in patients with subacromial impingement syndrome: Randomised controlled study. *BMJ, 344*, e787. https://doi.org/10.1136/bmj.e787

Klemt, C., Prinold, J. A., Morgans, S., Smith, S. H. L., Nolte, D., Reilly, P., & Bull, A. M. J. (2018). Analysis of shoulder compressive and shear forces during functional activities of daily life. *Clinical Biomechanics, 54*, 34–41. https://doi.org/10.1016/j.clinbiomech.2018.03.006

Silbernagel, K. G., Thomeé, R., Eriksson, B. I., & Karlsson, J. (2007). Continued sports activity, using a pain-monitoring model, during rehabilitation in patients with Achilles tendinopathy: A randomized controlled study. *The American Journal of Sports Medicine, 35*(6), 897–906. https://doi.org/10.1177/0363546506298279

Smith, B. E., Hendrick, P., Smith, T. O., Bateman, M., Moffatt, F., Rathleff, M. S., Selfe, J., & Logan, P. (2017). Should exercises be painful in the management of chronic musculoskeletal pain? A systematic review and meta-analysis. *British Journal of Sports Medicine, 51*(23), 1679–1687. https://doi.org/10.1136/bjsports-2016-097383

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

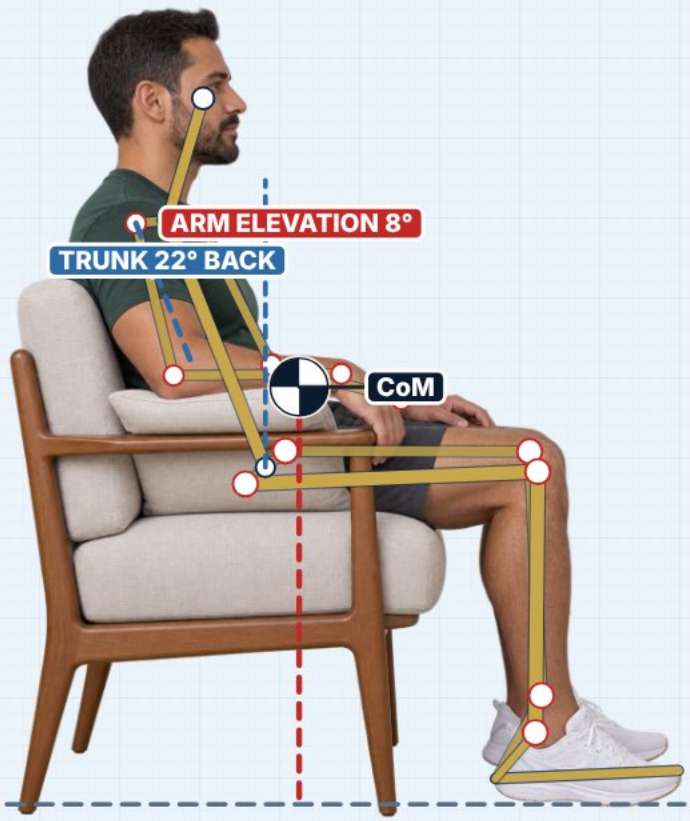
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

A SHOULDER PAIN FLARE-UP: HOW TO ADJUST YOUR TRAINING PLAN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

A · SUPPORTED REST, SIDE



Flare-ups are part of the course

- Resting reclined (trunk **22°** back) with the forearm on a pillow, arm at **8°**: the limb's weight is supported, so the cuff can relax.
- In primary care, recovery from new shoulder pain was slow and uneven; a flare-up is usually a cue to adjust dose, not a sign of new damage.

Recovery is slow in primary care



New episodes in general practice. van der Windt et al. (1996); Croft et al. (1996).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from hip–shoulder line vs vertical; arm elevation from trunk line to upper arm. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

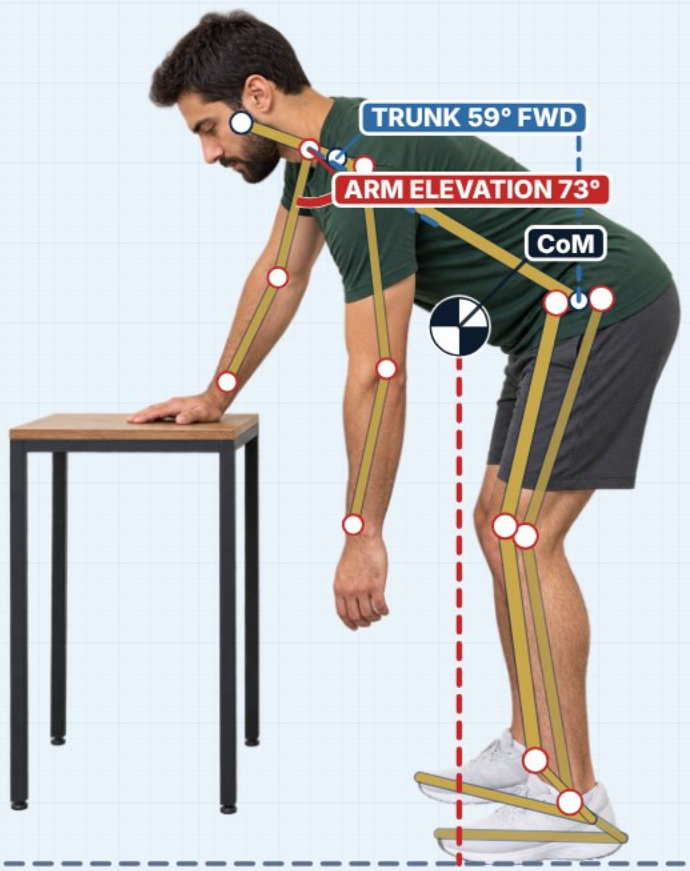
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

A SHOULDER PAIN FLARE-UP: HOW TO ADJUST YOUR TRAINING PLAN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

B · PENDULUM SWING, SIDE



Confidence predicts the outcome

- Pendulum: trunk **59°** forward with the arm hanging (**73°** from the trunk line), so gravity gives gentle movement with little muscle effort.
- Positive expectations and pain self-efficacy were linked with better outcomes; structural examination findings were not.

What predicts a better outcome



1,030 adults referred to physiotherapy, 811 followed to 6 months. Chester et al. (2018).

Myth: "A flare-up means I have re-injured it and must rest completely." Fluctuation is common; adjust the dose instead.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Trunk angle from hip–shoulder line vs vertical; arm elevation from trunk line to upper arm. Educational, not diagnostic.

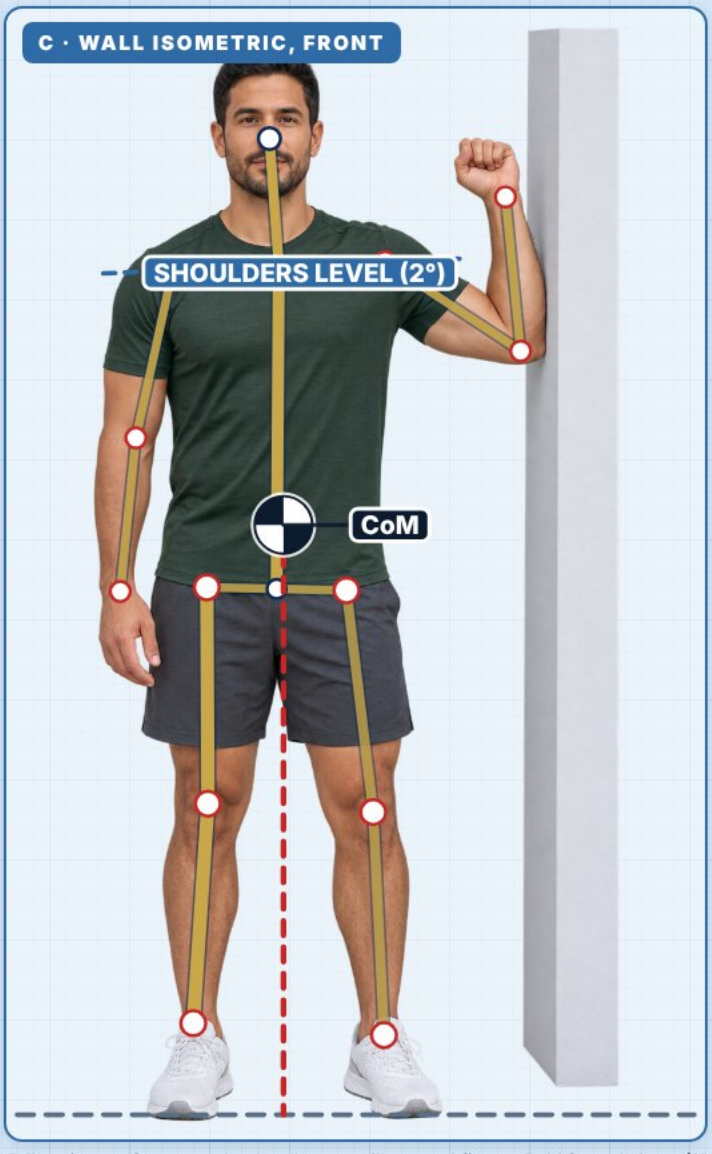
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

A SHOULDER PAIN FLARE-UP: HOW TO ADJUST YOUR TRAINING PLAN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

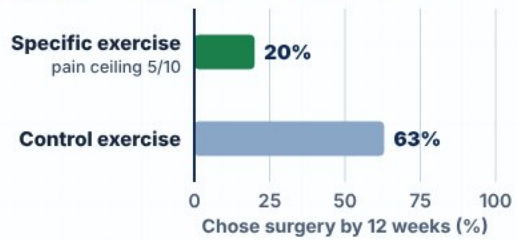


Work from explicit limits

Isometric hold with the elbow pressed into the wall, shoulders **2°** from level: effort without movement. The limits below come from a successful trial.

≤5/10	3 × 15	30–60 s
pain during exercise	twice daily, weeks 1–8	posterior stretch × 3, twice daily

The programme that used these limits



102 patients with long-standing impingement; cut sets or frequency first in a flare. Holmgren et al. (2012).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Flare-day exercises are examples, not trial-tested. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

A SHOULDER PAIN FLARE-UP: HOW TO ADJUST YOUR TRAINING PLAN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Supported rest
Arm weight supported

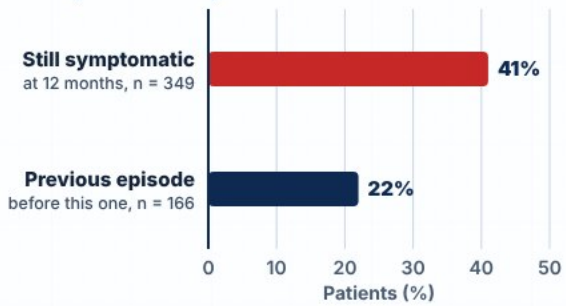


B · Pendulum
Trunk 59° forward



C · Wall isometric
Effort, no movement

Shoulder pain often persists or returns



Primary care cohorts: van der Windt et al. (1996); Croft et al. (1996).

Decision pathway

1. **SETTLE**
   Cut load, range, sets or frequency first and stay within the agreed ceiling, e.g. ≤5/10.
2. **KEEP MOVING**
   Use gentle pendulum, isometric holds and supported rest; keep the rest of the body training.
3. **REBUILD**
   Return to the planned dose over days as pain settles; build confidence, not fear.

NOT RECOMMENDED

Complete rest, or pushing through pain well above the agreed ceiling.

SEEK ASSESSMENT IF

No settling within a few weeks, fever or a hot swollen joint, constant severe night pain, new arm weakness or numbness, chest symptoms, or a fall.

REFERENCES (APA 7)

Chester, R., Jerosch-Herold, C., Lewis, J., & Shepstone, L. (2018). Psychological factors are associated with the outcome of physiotherapy for people with shoulder pain: A multicentre longitudinal cohort study. *British Journal of Sports Medicine, 52*(4), 269–275. https://doi.org/10.1136/bjsports-2016-096084

Croft, P., Pope, D., & Silman, A. (1996). The clinical course of shoulder pain: Prospective cohort study in primary care. *BMJ, 313*(7057), 601–602. https://doi.org/10.1136/bmj.313.7057.601

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Holmgren, T., Björnsson Hallgren, H., Öberg, B., Adolfsson, L., & Johansson, K. (2012). Effect of specific exercise strategy on need for surgery in patients with subacromial impingement syndrome: Randomised controlled study. *BMJ, 344*, e787. https://doi.org/10.1136/bmj.e787

van der Windt, D. A., Koes, B. W., Boeke, A. J., Devillé, W., De Jong, B. A., & Bouter, L. M. (1996). Shoulder disorders in general practice: Prognostic indicators of outcome. *British Journal of General Practice, 46*(410), 519–523.

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

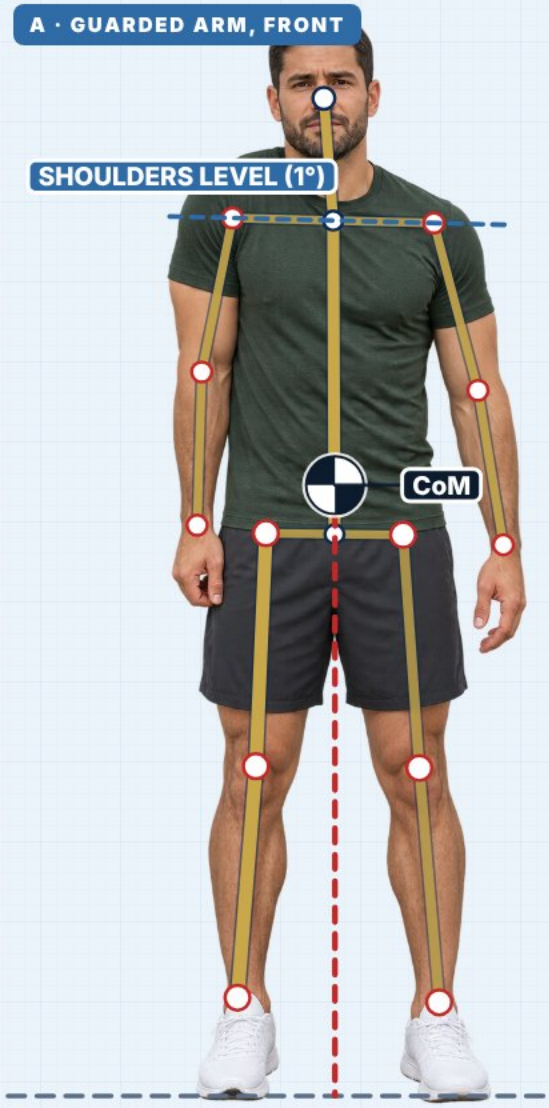
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FEAR OF MOVING A PAINFUL SHOULDER: HOW AVOIDANCE CHANGES MOVEMENT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

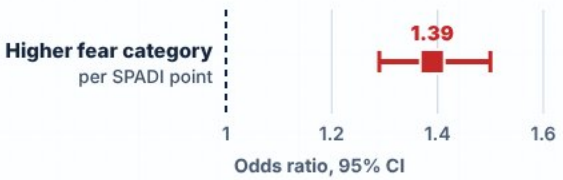
A · GUARDED ARM, FRONT



Guarding: the arm held still

- Arm held stiffly against the side, shoulder line **1°** from level: protecting the arm by not moving it is a common response to pain.
- In 208 adults with chronic subacromial pain, more pain-related disability went with more fear-avoidance; cross-sectional data cannot show which comes first.

Disability and fear-avoidance



Chilean adults, mean age 48; adjusted R^2 0.93; ≈6.7 points more fear per 10 SPADI points. González Aroca et al. (2023).

Key point: across 27 studies (11,176 people), fear-avoidance and catastrophising were associated with more pain and disability; evidence quality was very low.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

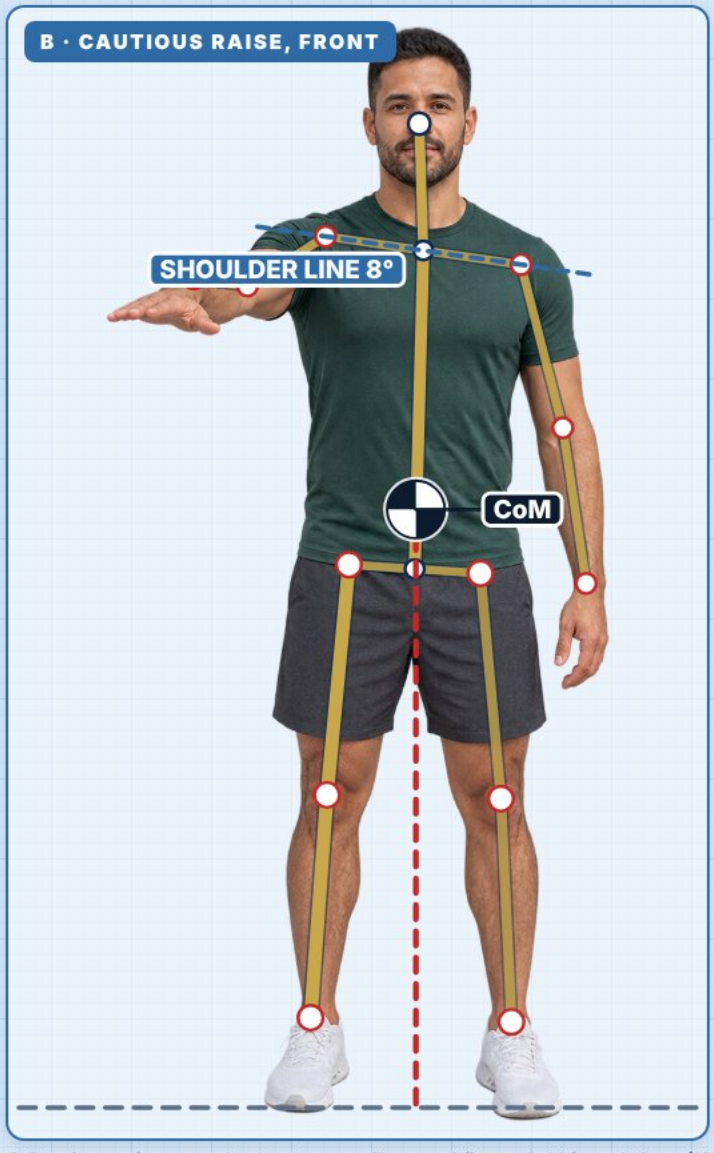
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FEAR OF MOVING A PAINFUL SHOULDER: HOW AVOIDANCE CHANGES MOVEMENT

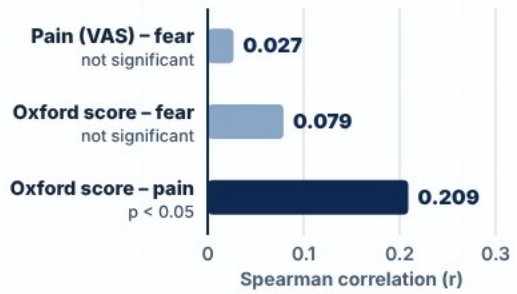
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Fear shows in range more than pain

- A cautious forward raise to part range, shoulders **8°** from level: the arm stops well short of overhead even when strength is available.
- In 102 patients, fear of movement was not linked to pain or Oxford score, but was weakly linked to less range; findings vary between studies.

Fear, pain and function (r)



102 patients with shoulder pathologies, mean age 53.7; fear measured with the Tampa Scale of Kinesiophobia. Özden et al. (2021).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view; forward raise not measured in this view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FEAR OF MOVING A PAINFUL SHOULDER: HOW AVOIDANCE CHANGES MOVEMENT

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

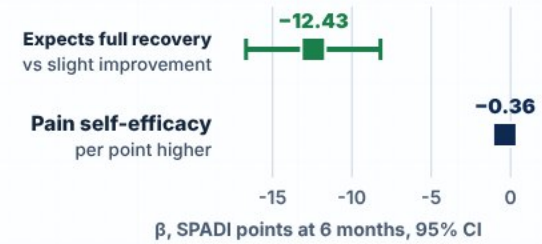
C · CONFIDENT REACH, FRONT



Confidence is the target

- Full overhead reach at **153°**, arm lever **≈12 cm**: reached in small, successful steps from the guarded position.
- Expecting a full recovery and confidence in managing pain were linked with lower disability after physiotherapy (negative β = better).

Beliefs that predict a better outcome



1,030 adults referred to physiotherapy, 811 followed to 6 months. Chester et al. (2018).

Myth: "Avoiding painful movement protects the shoulder." Painful exercise did not worsen longer-term outcomes in chronic pain trials.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

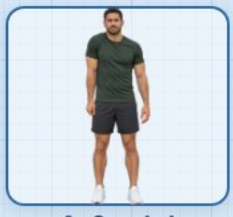
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

FEAR OF MOVING A PAINFUL SHOULDER: HOW AVOIDANCE CHANGES MOVEMENT

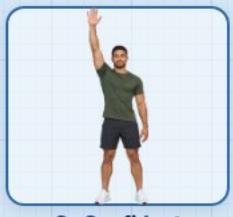
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Guarded
Arm held still



B · Cautious
Part range



C · Confident
Arm 153°

More fear, less range (weak links)



102 patients; all |r| below 0.3, so fear is one influence among many. Özden et al. (2021).

Decision pathway

1. **EXPLAIN**
   Pain during movement is not a reliable signal of damage; exercise can be done with acceptable pain.
2. **GRADE**
   Progress from guarded, to part range, to full reach in small steps that succeed.
3. **CONFIDENCE**
   Build self-efficacy and realistic, positive expectations of recovery.

NOT RECOMMENDED

Avoiding all painful movement, or assuming fear explains every limitation.

SEEK ASSESSMENT IF

True inability to lift the arm after an injury, progressive weakness, night pain with feeling unwell, or a hot swollen joint.

REFERENCES (APA 7)

Chester, R., Jerosch-Herold, C., Lewis, J., & Shepstone, L. (2018). Psychological factors are associated with the outcome of physiotherapy for people with shoulder pain: A multicentre longitudinal cohort study. *British Journal of Sports Medicine, 52*(4), 269–275. https://doi.org/10.1136/bjsports-2016-096084

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

González Aroca, J., Puelles Díaz, Á., Navarrete, C., & Albarnez, L. (2023). Fear-avoidance beliefs are associated with pain intensity and shoulder disability in adults with chronic shoulder pain: A cross-sectional study. *Journal of Clinical Medicine, 12*(10), 3376. https://doi.org/10.3390/jcm12103376

Martinez-Calderon, J., Meeus, M., Struyf, F., Morales-Asencio, J. M., Gijon-Nogueron, G., & Luque-Suarez, A. (2018). The role of psychological factors in the perpetuation of pain intensity and disability in people with chronic shoulder pain: A systematic review. *BMJ Open, 8*, e020703. https://doi.org/10.1136/bmjopen-2017-020703

Smith, B. E., Hendrick, P., Smith, T. O., Bateman, M., Moffatt, F., Rathleff, M. S., Selfe, J., & Logan, P. (2017). Should exercises be painful in the management of chronic musculoskeletal pain? A systematic review and meta-analysis. *British Journal of Sports Medicine, 51*(23), 1679–1687. https://doi.org/10.1136/bjsports-2016-097383

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Özden, F., Tuğay, N., Karaman, Ö. N., Kilinç, C. Y., & Tuğay, B. U. (2021). The relationship of fear of movement with pain, range of motion and function in patients with shoulder pathologies. Bulletin of Faculty of Physical Therapy. https://doi.org/10.1186/s43161-021-00020-4

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

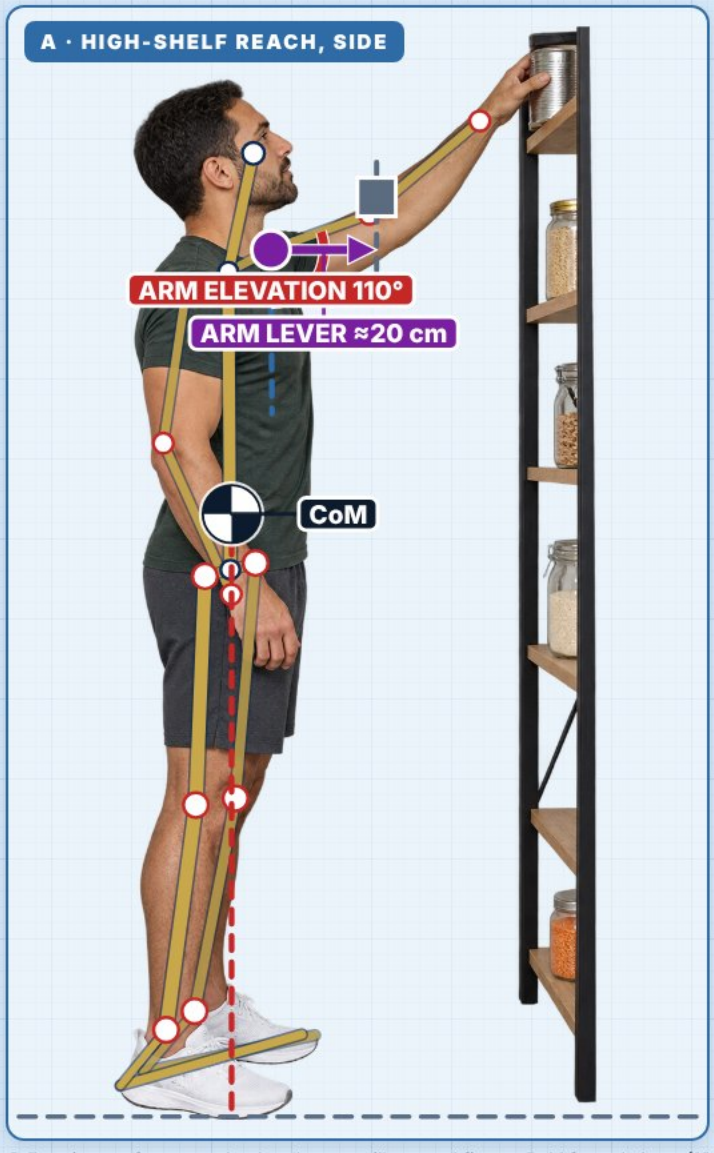
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

IS YOUR SHOULDER REHABILITATION WORKING? TRACK FUNCTION ALONGSIDE PAIN

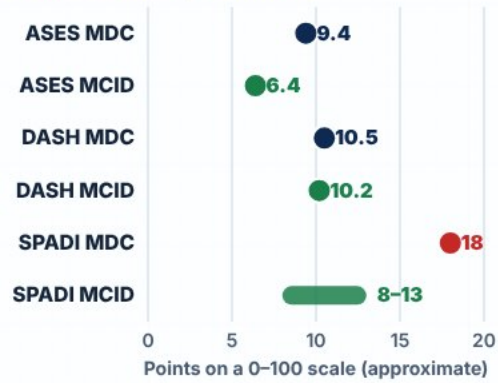
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



Noise versus real change

- Placing a can on a high shelf, arm at **110°** with a lever of **≈20 cm**: a real task worth retesting alongside questionnaires.
- A change must beat measurement error (MDC) to be trusted and reach the MCID to matter; for SPADI the MDC is larger than the MCID.

How much change matters



71 psychometric studies of shoulder questionnaires. Roy et al. (2009).

Myth: "A few points better on SPADI is real improvement." Judge progress over several measurements, not one.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

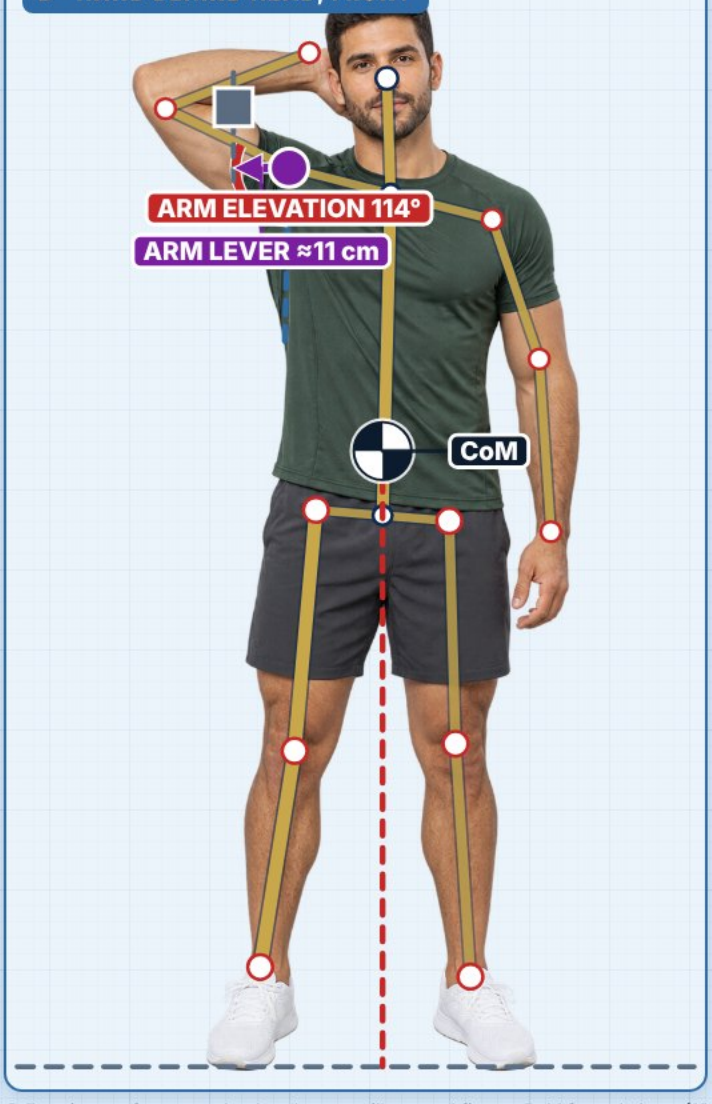
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

IS YOUR SHOULDER REHABILITATION WORKING? TRACK FUNCTION ALONGSIDE PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

B · HAND BEHIND HEAD, FRONT



The threshold depends on method

- Hand behind the head, arm at **114°** (lever ≈**11 cm**): a reach used for hair care and dressing that is easy to score.
- MCIDs differ by population and method, so quote a value derived in people similar to the patient.

Oxford Shoulder Score MCID



45 shoulder replacements for osteoarthritis, scored before and at one year. Nyring et al. (2021).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Arm lever: shoulder joint to arm CoM; moment = arm weight × lever, 70 kg adult, static. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

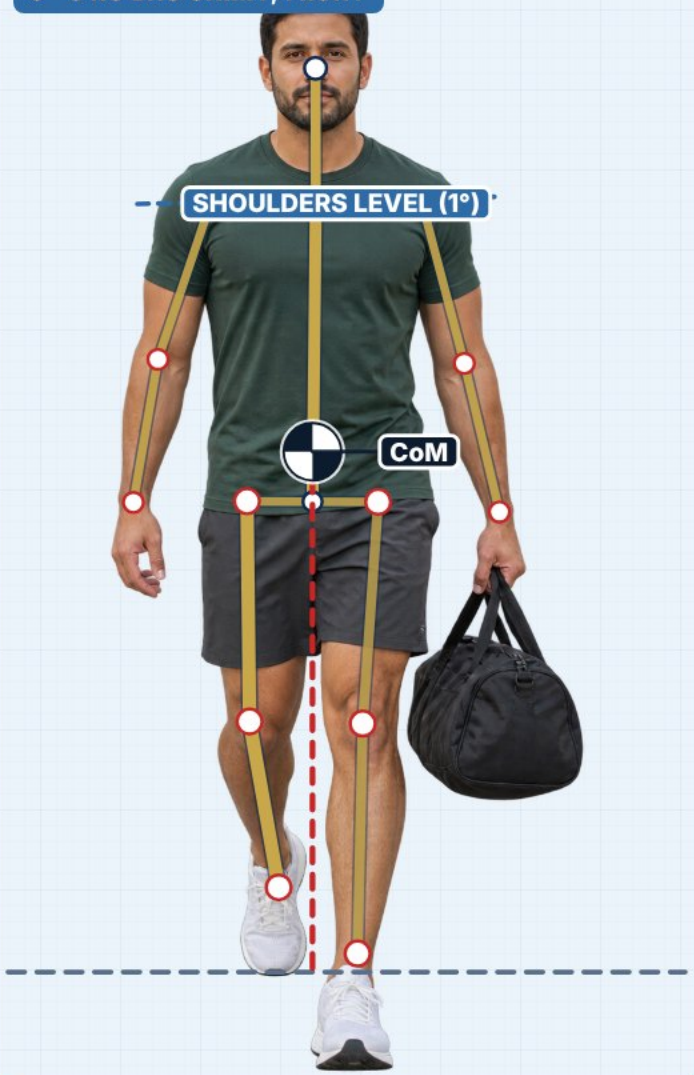
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

IS YOUR SHOULDER REHABILITATION WORKING? TRACK FUNCTION ALONGSIDE PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

C · 5 KG BAG CARRY, FRONT



Scores track pain more than capacity

- Carrying a 5 kg bag with the shoulders level (**1°**): a simple timed or loaded test of real function.
- In subacromial pain, pain explained 23.4–31.6% of SPADI variance, while strength and range did not, despite clear deficits.

Deficits a questionnaire can miss



87 patients with a pain-free opposite shoulder, from 157 consecutive. Clausen et al. (2017).

Key point: track a performance measure alongside pain and questionnaire scores.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line from left and right shoulder points in the front view. Educational, not diagnostic.

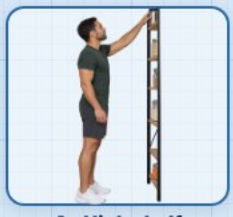
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

IS YOUR SHOULDER REHABILITATION WORKING? TRACK FUNCTION ALONGSIDE PAIN

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · High shelf
Arm 110°



B · Behind head
Arm 114°



C · 5 kg carry
Timed or loaded

A trial benchmark for meaningful change



Subacromial pain, 12 weeks; patient-rated success 69% vs 24%. Holmgren et al. (2012).

Decision pathway

1. **QUESTIONNAIRE**
   Record SPADI, QuickDASH or Oxford score every 2–4 weeks (Grade A).
2. **MEASURE**
   Measure range with an inclinometer or app and strength with a dynamometer (Grade A).
3. **JUDGE**
   Trust change beyond the MDC over several tests; refer if severe after 12 weeks of care.

NOT RECOMMENDED

Judging progress by pain alone, or by one small change in a score.

SEEK ASSESSMENT IF

Worsening scores despite a well-delivered plan, new night pain with feeling unwell, or progressive weakness.

REFERENCES (APA 7)

Clausen, M. B., Witten, A., Holm, K., Christensen, K. B., Attrup, M. L., Hölmich, P., & Thorborg, K. (2017). Glenohumeral and scapulothoracic strength impairments exists in patients with subacromial impingement, but these are not reflected in the shoulder pain and disability index. *BMC Musculoskeletal Disorders, 18*, 302. https://doi.org/10.1186/s12891-017-1667-1

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Holmgren, T., Björnsson Hallgren, H., Öberg, B., Adolfsson, L., & Johansson, K. (2012). Effect of specific exercise strategy on need for surgery in patients with subacromial impingement syndrome: Randomised controlled study. *BMJ, 344*, e787. https://doi.org/10.1136/bmj.e787

Nyring, M. R. K., Olsen, B. S., Amundsen, A., & Rasmussen, J. V. (2021). Minimal clinically important differences (MCID) for the Western Ontario Osteoarthritis of the Shoulder Index (WOOS) and the Oxford Shoulder Score (OSS). *Patient Related Outcome Measures, 12*, 299–306. https://doi.org/10.2147/PROM.S316920

Roy, J.-S., MacDermid, J. C., & Woodhouse, L. J. (2009). Measuring shoulder function: A systematic review of four questionnaires. *Arthritis & Rheumatism (Arthritis Care & Research), 61*(5), 623–632. https://doi.org/10.1002/art.24396

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

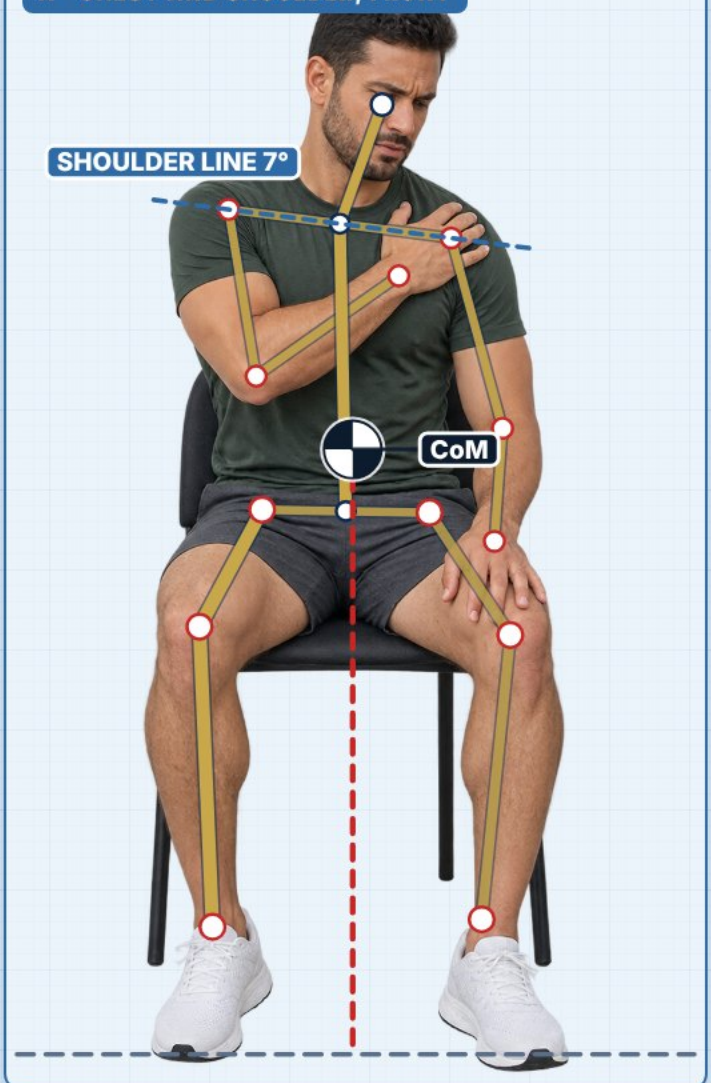
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER RED FLAGS: WHEN SHOULDER PAIN NEEDS URGENT MEDICAL CARE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

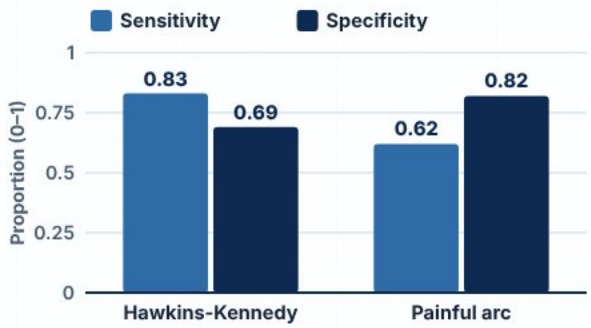
A · CHEST AND SHOULDER, FRONT



Chest symptoms come first

- Shoulder or arm pain with chest pressure, breathlessness, sweating, nausea or onset on exertion is an emergency until proven otherwise: call emergency services, do not exercise.
- Shoulder tests help diagnose cuff problems, but a positive test does not rule out a heart or other visceral cause.

Shoulder tests for cuff tendinopathy



Pooled accuracy as reported in the 2025 guideline (secondary summary). Desmeules et al. (2025).

Myth: "Shoulder pain is always a shoulder problem." The guideline lists cardiac and visceral causes, infection and cancer for screening.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line 7° from left and right shoulder points in the front view. Educational, not diagnostic.

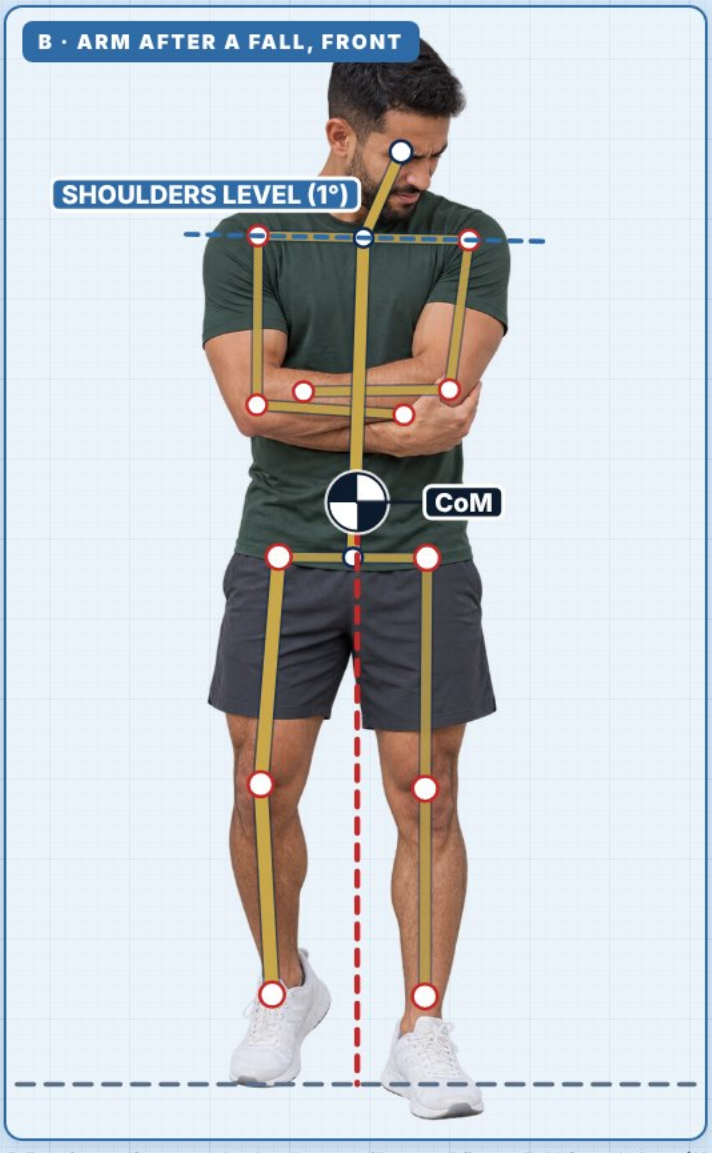
MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER RED FLAGS: WHEN SHOULDER PAIN NEEDS URGENT MEDICAL CARE

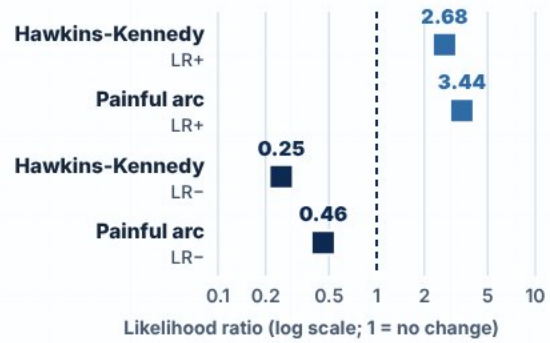
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



After a fall: rule out fracture

- Supporting the arm after a fall with deformity, severe pain, swelling or bruising needs same-day assessment and an X-ray for fracture or dislocation.
- Clinical tests only shift the odds of a cuff problem; they cannot exclude a fracture, so history comes first.

How far a test result shifts the odds



Rotator cuff tendinopathy tests, guideline summary of pooled data. Desmeules et al. (2025).

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line 1° from left and right shoulder points in the front view. No load or angle quoted. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

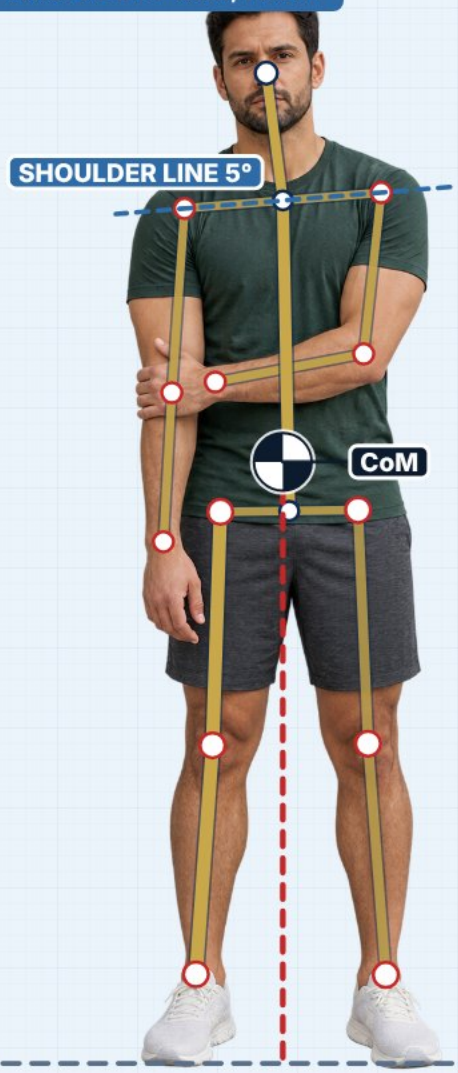
BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER RED FLAGS: WHEN SHOULDER PAIN NEEDS URGENT MEDICAL CARE

AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS

C · CANNOT LIFT ARM, FRONT



Sudden loss of lifting needs review

- Sudden inability to lift the arm after an injury needs prompt medical assessment; surgery is appropriate for selected people with full-thickness tears.
- Shoulder complaints are common in general practice and cuff tendinitis is the most recorded diagnosis (29%), so serious causes stand out only with structured screening.

Shoulder complaints are common



Dutch general practice. van der Windt et al. (1995).

Also urgent: fever or chills with a hot, swollen, very painful joint (possible infection); new progressive weakness or numbness in the arm.

2-D estimates from pose landmarks on an illustrated figure; CoM from de Leva (1996) segment parameters; cm for a 1.70 m adult (Winter, 2009). Shoulder line 5° from left and right shoulder points in the front view. Educational, not diagnostic.

MMSx Authority
APPLIED BIOMECHANICS LAB
DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.

SHOULDER RED FLAGS: WHEN SHOULDER PAIN NEEDS URGENT MEDICAL CARE

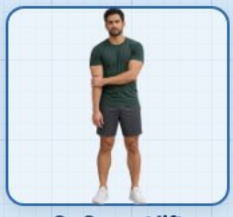
AN MMSX AUTHORITY | APPLIED BIOMECHANICS LAB EDUCATIONAL ANALYSIS



A · Chest symptoms
Emergency

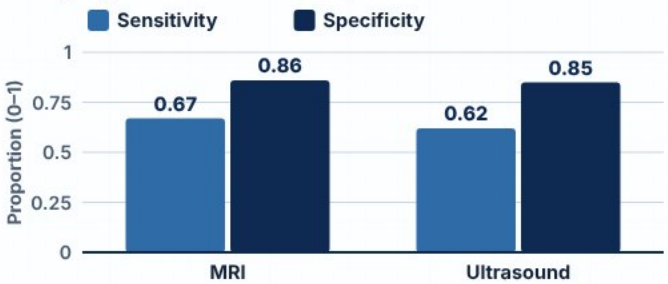


B · After a fall
Same-day X-ray



C · Cannot lift
Prompt review

Imaging is not the first step



Partial-thickness cuff tears, network meta-analysis reported in the 2025 guideline. Desmeules et al. (2025).

Decision pathway

1. **URGENT**
   Chest symptoms, deformity after trauma, fever with a hot joint, sudden loss of function: same day.
2. **PROMPT**
   Cancer history, unexplained weight loss, constant night pain or a non-mechanical pattern: within days.
3. **ROUTINE**
   Severe, persistent pain after up to 12 weeks of good non-surgical care: specialist referral.

NOT RECOMMENDED

Exercising through red-flag symptoms; a scan as the first step instead of history and screening.

SEEK ASSESSMENT IF

Any urgent sign: emergency or same-day care. Pain that fits no mechanical pattern or does not resolve: reassess (neck, fracture, tumour, infection).

REFERENCES (APA 7)

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics, 29*(9), 1223–1230. https://doi.org/10.1016/0021-9290(95)00178-6

Desmeules, F., Roy, J.-S., Lafrance, S., Charron, M., Dubé, M.-O., Dupuis, F., Beneciuk, J. M., Grimes, J., Kim, H. M., Lamontagne, M., McCreesh, K., Shanley, E., Vukobrat, T., & Michener, L. A. (2025). Rotator cuff tendinopathy diagnosis, nonsurgical medical care, and rehabilitation: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 55*(4), 235–274. https://doi.org/10.2519/jospt.2025.13182

Kelley, M. J., Shaffer, M. A., Kuhn, J. E., Michener, L. A., Seitz, A. L., Uhl, T. L., Godges, J. J., & McClure, P. W. (2013). Shoulder pain and mobility deficits: Adhesive capsulitis. Clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy, 43*(5), A1–A31. https://doi.org/10.2519/jospt.2013.0302

Lafrance, S., Charron, M., Roy, J.-S., Dyer, J.-O., Frémont, P., Dionne, C. E., MacDermid, J. C., Tousignant, M., Rochette, A., Doiron-Cadrin, P., Lowry, V., Bureau, N., Lamontagne, M., Sandman, E., Coutu, M.-F., Lavigne, P., & Desmeules, F. (2022). Diagnosing, managing, and supporting return to work of adults with rotator cuff disorders: A clinical practice guideline. *Journal of Orthopaedic & Sports Physical Therapy, 52*(10), 647–664. https://doi.org/10.2519/jospt.2022.11306

van der Windt, D. A., Koes, B. W., de Jong, B. A., & Bouter, L. M. (1995). Shoulder disorders in general practice: Incidence, patient characteristics, and management. *Annals of the Rheumatic Diseases, 54*(12), 959–964. https://doi.org/10.1136/ard.54.12.959

Winter, D. A. (2009). *Biomechanics and motor control of human movement* (4th ed.). Wiley. https://doi.org/10.1002/9780470549148

Analysis: MMSx Authority Applied Biomechanics Lab · Dr. Neeraj Mehta, PhD · Educational content, not a diagnosis.

DOI 10.5281/zenodo.23735725

BIOMECHANICS IS A FORCE-GOVERNED DECISION SYSTEM – NOT A POSTURE MODEL.

INTEGRATING PERFORMANCE & REHABILITATION HEALTHCARE PATHWAYS.