



Joint Mobility and Stability Strategies for the Shoulder

Independent Study
Course 29.2.2

Mary Insana Fisher, PT, PhD, OCS

Associate Professor, Department of Physical Therapy
School of Education and Health Sciences
University of Dayton
Dayton, OH

J. Matthew Day, PT, PhD, OCS

Assistant Professor, Department of Physical Therapy
School of Education and Health Sciences
University of Dayton
Dayton, OH

CONTINUING PHYSICAL THERAPY EDUCATION



REFERENCES

1. Luime JJ, Koes BW, Hendriksen IJM, et al. Prevalence and incidence of shoulder pain in the general population: a systematic review. *Scand J Rheumatol.* 2004;33:73-81.
2. Walker-Bone K, Reading I, Coggon D, Cooper C, Palmer KT. The anatomical pattern and determinants of pain in the neck and upper limbs: an epidemiologic study. *Pain.* 2004;109:45-51.
3. Kilic O, Maas M, Verhagen E, Zwerver J, Gouttebarge V. Incidence, aetiology and prevention of musculoskeletal injuries in volleyball: A systematic review of the literature. *Eur J Sport Sci.* 2017;17:765-793. doi: 10.1080/17461391.2017.1306114. Epub 2017 Apr 9.
4. Young SW, Dakic J, Stroia K, Nguyen ML, Harris AH, Safran MR. High Incidence of infraspinatus muscle atrophy in elite professional female tennis players. *Am J Sports Med.* 2015;43:1989-1993. doi: 10.1177/0363546515588177. Epub 2015 Jun 15.
5. Oyama S, Yu B, Blackburn JT, Padua DA, Li L, Myers JB. Improper rotation sequence is associated with increased maximal shoulder external rotation angle and shoulder joint force in high school baseball pitchers. *Am J Sports Med.* 2014;42:2089-2094. doi: 10.1177/0363546514536871. Epub 2014 Jun 18.
6. Harrington S, Meisel C, Tate A. A cross-sectional study examining shoulder pain and disability in division I female swimmers. *J Sport Rehabil.* 2014;23:65-75. doi: 10.1123/jsr.2012-0123. Epub 2013 Aug 12.
7. Tate A, Turner GN, Knab SE, Jorgensen C, Strittmatter A, Michener LA. Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. *J Athl Train.* 2012;47:149-58.
8. Silverstein BA, Viikari-Juntura E, Fan ZJ, Bonauto DK, Bao S, Smith C. Natural course of nontraumatic rotator cuff tendinitis and shoulder symptoms in a working population. *Scand J Work Environ Health.* 2006;32:99-108.
9. Cadogan A, Laslett M, Hing WA, McNair PJ, Coates MH. A prospective study of shoulder pain in primary care: prevalence of imaged pathology and response to guided diagnostic blocks. *BMC Musculoskelet Disord.* 2011;12:119. doi: 10.1186/1471-2474-12-119.
10. US Bureau of Labor Statistics. Brandley C. Workplace injuries and illnesses and employer costs for workers' compensation. <https://www.bls.gov/spotlight/2016/workplace-injuries-and-illnesses-and-employer-costs-for-workers-compensation/home.htm>. Accessed January 15, 2019.
11. Oberlander MA, Chesar MA, Campbell B. Epidemiology of shoulder injuries in throwing and overhead athletes. *Sports Med Arthrosc Rev.* 2000;8:115-123.
12. Summitt RJ, Cotton RA, Kays AC, Slaven EJ. Shoulder injuries in individuals who participate in crossfit training. *Sports Health.* 2016;8:541-546. doi: 10.1177/1941738116666073. Epub 2016 Sep 20.
13. Zumstein V, Kraljević M, Hoechel S, Conzen A, Nowakowski AM, Müller-Gerbl M. The glenohumeral joint - a mismatching system? A morphological analysis of the cartilaginous and osseous curvature of the humeral head and the glenoid cavity. *J Orthop Surg Res.* 2014;9:34. doi: 10.1186/1749-799X-9-34.
14. Howell SM, Galinat BJ. The glenoid-labral socket. A constrained articular surface. *Clin Orthop Relat Res.* 1989;(243):122-125.
15. Bigliani LU, Kelkar R, Flatow EL, Pollock RG, Mow VC. Glenohumeral stability. Biomechanical properties of passive and active stabilizers. *Clin Orthop Relat Res.* 1996;(330):13-30.
16. Levangie PK, Norkin CC. *Joint Structure and Function: A Comprehensive Analysis.* 5th ed. Philadelphia, PA: F.A. Davis Co.; 2011.
17. Kibler WB. Shoulder rehabilitation: principles and practice. *Med Sci Sports Exerc.* 1998;30(4 Suppl):S40-50.
18. Kibler W. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26(2):325-337.
19. Kibler WB, Sciascia A. Current concepts: scapular dyskinesis. *Br J Sports Med.* 2010;44(5):300-305. doi: 10.1136/bjsm.2009.058834. Epub 2009 Dec 8.
20. Laudner KG, Myers JB, Pasquale MR, Bradley JP, Lephart SM. Scapular dysfunction in throwers with pathologic internal impingement. *J Orthop Sports Phys Ther.* 2006;36(7):485-494.
21. Kibler WB, Ludewig PM, McClure PW, Michener LA, Bak K, Sciascia AD. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'Scapular Summit'. *Br J Sports Med.* 2013;47(14):877-885. doi: 10.1136/bjsports-2013-092425. Epub 2013 Apr 11.
22. McQuade KJ, Borstad J, de Oliveira AS. Critical and theoretical perspective on scapular stabilization: what does it really mean, and are we on the right track? *Phys Ther.* 2016;96(8):1162-1169. doi: 10.2522/ptj.20140230. Epub 2016 Feb 4.
23. Pires ED, Camargo PR. Analysis of the kinetic chain in asymptomatic individuals with and without scapular dyskinesis. *Clin Biomech (Bristol, Avon).* 2018;54:8-15. doi: 10.1016/j.clinbiomech.2018.02.017. Epub 2018 Feb 27.
24. Plummer HA, Sum JC, Pozzi F, Varghese R, Michener LA. Observational scapular dyskinesis: known-groups validity in patients with and without shoulder pain. *J Orthop Sports Phys Ther.* 2017;47(8):530-537. doi: 10.2519/jospt.2017.7268. Epub 2017 Jul 6.
25. Hannah DC, Scibek JS, Garcia CR. Strength profiles in healthy individuals with and without scapular dyskinesis. *Int J Sports Phys Ther.* 2017;12(3):305-313.

26. Seitz AL, McClelland RI, Jones WJ, Jean RA, Kardouni JR. A comparison of change in 3D scapular kinematics with maximal contractions and force production with scapular muscle tests between asymptomatic overhead athletes with and without scapular dyskinesis. *Int J Sports Phys Ther.* 2015;10(3):309-318.
27. Vanderstukken F, Jansen N, Mertens T, Cools AM. Elite male field hockey players have symmetric isokinetic glenohumeral strength profiles, but show asymmetry in scapular muscle strength. *J Sports Sci.* 2019;37(5):484-491. doi: 10.1080/02640414.2018.1507238. Epub 2018 Aug 3.
28. Uhl TL, Kibler WB, Gecewich B, Tripp BL. Evaluation of clinical assessment methods for scapular dyskinesis. *Arthroscopy.* 2009;25(11):1240-1248. doi: 10.1016/j.arthro.2009.06.007.
29. Hodges PW, Moseley GL. Pain and motor control of the lumbopelvic region: effect and possible mechanisms. *J Electromyogr Kinesiol.* 2003;13(4):361-370.
30. Grimstone SK, Hodges PW. Impaired postural compensation for respiration in people with recurrent low back pain. *Exp Brain Res.* 2003;151(2):218-224.
31. Suter E, Herzog W, De Souza K, Bray R. Inhibition of the quadriceps muscles in patients with anterior knee pain. *J Appl Biomech.* 1998;14(4):360-373.
32. Ben-Yishay A, Zuckerman JD, Gallagher M, Cuomo F. Pain inhibition of shoulder strength in patients with impingement syndrome. *Orthopedics.* 1994;17(8):685-688.
33. Lomond KV, Cote JN. Movement timing and reach to reach variability during a repetitive reaching task in persons with chronic neck/shoulder pain and healthy subjects. *Exp Brain Res.* 2010;206(3):271-282. doi: 10.1007/s00221-010-2405-1. Epub 2010 Sep 17.
34. Madeleine P, Mathiassen SE, Arendt-Nielsen L. Changes in the degree of motor variability associated with experimental and chronic neck-shoulder pain during a standardised repetitive arm movement. *Exp Brain Res.* 2008;185(4):689-698.
35. Zhang AL, Theologis AA, Tay B, Feeley BT. The association between cervical spine pathology and rotator cuff dysfunction. *J Spinal Disord Tech.* 2015;28(4):E206-211. doi: 10.1097/BSD.0000000000000223.
36. Hidalgo-Lozano A, Calderon-Soto C, Domingo-Camara A, Fernandez-de-Las-Penas C, Madeleine P, Arroyo-Morales M. Elite swimmers with unilateral shoulder pain demonstrate altered pattern of cervical muscle activation during a functional upper-limb task. *J Orthop Sports Phys Ther.* 2012;42(6):552-558. doi: 10.2519/jospt.2012.3875.
37. Calvo Lobo C, Romero Morales C, Rodriguez Sanz D, et al. Comparison of hand grip strength and upper limb pressure pain threshold between older adults with or without non-specific shoulder pain. *Peer J.* 2017;5:e2995. doi: 10.7717/peerj.2995. eCollection 2017.
38. Namdari S, Yagnik G, Ebaugh DD, et al. Defining functional shoulder range of motion for activities of daily living. *J Shoulder Elbow Surg.* 2012;21(9):1177-1183. doi: 10.1016/j.jse.2011.07.032. Epub 2011 Nov 1.
39. Lomond KV, Cote JN. Differences in posture-movement changes induced by repetitive arm motion in healthy and shoulder-injured individuals. *Clin Biomech (Bristol, Avon).* 2011;26(2):123-129. doi: 10.1016/j.clinbiomech.2010.09.012. Epub 2010 Oct 15.
40. Foster MA. *Therapeutic Kinesiology.* Boston, MA: Pearson; 2013.
41. Hardwick DH, Beebe JA, McDonnell MK, Lang CE. A comparison of serratus anterior muscle activation during a wall slide exercise and other traditional exercises. *J Orthop Sports Phys Ther.* 2006;36(12):903-910.
42. Hardwick DD, Lang CE. Scapula and humeral movement patterns and their relationship with pain: A preliminary investigation. *Int J Ther Rehabil.* 2011;18(4):210-220.
43. Bouaicha S, Slankamenac K, Moor BK, Tok S, Andreisek G, Finkenstaedt T. Cross-sectional area of the rotator cuff muscles in MRI - Is there evidence for a biomechanical balanced shoulder? *PLoS One.* 2016;11(6):e0157946. doi: 10.1371/journal.pone.0157946. eCollection 2016.
44. Lubiatowski P, Kaczmarek P, Cisowski P, et al. Rotational glenohumeral adaptations are associated with shoulder pathology in professional male handball players. *Knee Surg Sports Traumatol Arthrosc.* 2018;26(1):67-75. doi: 10.1007/s00167-017-4426-9. Epub 2017 Feb 15.
45. Trakis JE, McHugh MP, Caracciolo PA, Busciacco L, Mullaney M, Nicholas SJ. Muscle strength and range of motion in adolescent pitchers with throwing-related pain: implications for injury prevention. *Am J Sports Med.* 2008;36(11):2173-2178. doi: 10.1177/0363546508319049. Epub 2008 Jul 2.
46. Wassinger CA, Sole G, Osborne H. The role of experimentally-induced subacromial pain on shoulder strength and throwing accuracy. *Man Ther.* 2012;17(5):411-415. doi: 10.1016/j.math.2012.03.008. Epub 2012 Apr 13.
47. Schwesig R, Hermassi S, Wagner H, et al. Relationship between the range of motion and isometric strength of elbow and shoulder joints and ball velocity in women team handball players. *J Strength Cond Res.* 2016;30(12):3428-3435.
48. Norlander S, Nordgren B. Clinical symptoms related to musculoskeletal neck-shoulder pain and mobility in the cervico-thoracic spine. *Scand J Rehabil Med.* 1998;30(4):243-251.
49. Horsley I, Herrington L, Hoyle R, Prescott E, Bellamy N. Do changes in hand grip strength correlate with shoulder rotator cuff function? *Shoulder Elbow.* 2016;8(2):124-129. doi: 10.1177/1758573215626103. Epub 2016 Jan 25.
50. Hassaballa M, Artz N, Weale A, Porteous A. Alteration in skin sensation following knee arthroplasty and its impact on kneeling ability: a comparison of three common surgical incisions. *Knee Surg Sports Traumatol Arthrosc.* 2012;20(10):1983-1987.

51. Lam DK, Sessle BJ, Hu JW. Surgical incision can alter capsaicin-induced central sensitization in rat brainstem nociceptive neurons. *Neuroscience*. 2008;156(3):737-747. doi: 10.1016/j.neuroscience.2008.07.058. Epub 2008 Aug 5.
52. Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. *Pain*. 2011;152(3 Suppl):S2-15. doi: 10.1016/j.pain.2010.09.030. Epub 2010 Oct 18.
53. Noten S, Struyf F, Lluch E, D'Hoore M, Van Looveren E, Meeus M. Central pain processing in patients with shoulder pain: a review of the literature. *Pain Pract*. 2017;17(2):267-280. doi: 10.1111/papr.12502. Epub 2016 Oct 14.
54. Vadivelu N, Mitra S, Schermer E, Kodumudi V, Kaye AD, Urman RD. Preventive analgesia for postoperative pain control: a broader concept. *Local Reg Anesth*. 2014;7:17-22. doi: 10.2147/LRA.S62160. eCollection 2014.
55. Diederichsen L, Krogsbaard M, Voigt M, Dyhre-Poulsen P. Shoulder reflexes. *J Electromyogr Kinesiol*. 2002;12(3):183-191.
56. Mintken PE, Cleland JA, Whitman JM, George SZ. Psychometric properties of the Fear-Avoidance Beliefs Questionnaire and Tampa Scale of Kinesiophobia in patients with shoulder pain. *Arch Phys Med Rehabil*. 2010;91(7):1128-1136. doi: 10.1016/j.apmr.2010.04.009.
57. Knepler C, Bohannon RW. Subjectivity of forces associated with manual-muscle test grades of 3+, 4-, and 4. *Percept Mot Skills*. 1998;87(3 Pt 2):1123-1128.
58. Janssen JC, Le-Ngoc L. Intratester reliability and validity of concentric measurements using a new hand-held dynamometer. *Arch Phys Med Rehabil*. 2009;90:1541-7. doi: 10.1016/j.apmr.2009.02.021.
59. Johansson FR, Skillgate E, Lapauw ML, et al. Measuring eccentric strength of the shoulder external rotators using handheld dynamometer: reliability and validity. *J Athl Train*. 2015;50:719-25. doi: 10.4085/1062-6050-49.3.72. Epub 2015 May 14.
60. Wainner RS, Fritz JM, Irrgang JJ, Boninger ML, Delitto A, Allison S. Reliability and diagnostic accuracy of the clinical examination and patient self-report measures for cervical radiculopathy. *Spine (Phila Pa 1976)*. 2003;28(1):52-62.
61. Sandmark H, Nisell R. Validity of five common manual neck pain provoking tests. *Scand J Rehabil Med*. 1995;27(3):131-136.
62. Nee RJ, Jull GA, Vicenzino B, Coppieters MW. The validity of upper-limb neurodynamic tests for detecting peripheral neuropathic pain. *J Orthop Sports Phys Ther*. 2012;42(5):413-424. doi: 10.2519/jospt.2012.3988. Epub 2012 Mar 8.
63. Struyf F, Nijs J, Mottram S, Roussel NA, Cools AMJ, Meeusen R. Clinical assessment of the scapula: a review of the literature. *Br J Sports Med*. 2014;48(11):883-890. doi: 10.1136/bjsports-2012-091059. Epub 2012 Jul 21.
64. Curtis T, Roush JR. The Lateral Scapular Slide Test: a reliability study of males with and without shoulder pathology. *N Am J Sports Phys Ther*. 2006;1(3):140-146.
65. Shadmehr A, Azarsa MH, Jalaie S. Inter- and intrarater reliability of modified lateral scapular slide test in healthy athletic men. *Biomed Res Int*. 2014;2014:384149. doi: 10.1155/2014/384149. Epub 2014 May 13.
66. Shadmehr A, Sarafraz H, Heidari Blooki M, Jalaie SH, Morais N. Reliability, agreement, and diagnostic accuracy of the Modified Lateral Scapular Slide test. *Man Ther*. 2016;24:18-24. doi: 10.1016/j.math.2016.04.004. Epub 2016 Apr 19.
67. Kibler WB, Sciascia A, Dome D. Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. *Am J Sports Med*. 2006;34(10):1643-1647.
68. Khazzam M, Gates ST, Tisano BK, Kukowski N. Diagnostic accuracy of the scapular retraction test in assessing the status of the rotator cuff. *Orthop J Sports Med*. 2018;6(10):2325967118799308. doi: 10.1177/2325967118799308. eCollection 2018 Oct.
69. Kibler WB, Uhl TL, Cunningham TJ. The effect of the Scapular Assistance Test on scapular kinematics in the clinical exam [Abstract]. *J Orthop Sports Phys Ther*. 2009;39(11):A12-A12.
70. Rabin A, Irrgang JJ, Fitzgerald GK, Eubanks A. The intertester reliability of the Scapular Assistance Test. *J Orthop Sports Phys Ther*. 2006;36(9):653-660.
71. Kopkow C, Lange T, Schmitt J, Kasten P. Interrater reliability of the modified scapular assistance test with and without handheld weight. *Man Ther*. 2015;20(6):868-874. doi: 10.1016/j.math.2015.04.012. Epub 2015 Apr 16.
72. MacDermid JC, Ghobrial M, Quirion KB, et al. Validation of a new test that assesses functional performance of the upper extremity and neck (FIT-HaNSA) in patients with shoulder pathology. *BMC Musculoskelet Disord*. 2007;8:42.
73. Hayes S, Battistutta D, Newman B. Objective and subjective upper body function six months following diagnosis of breast cancer. *Breast Cancer Res Treat*. 2005;94(1):1-10.
74. Ager AL, Roy J-S, Roos M, Belley AF, Cools A, Hébert LJ. Shoulder proprioception: How is it measured and is it reliable? A systematic review. *J Hand Ther*. 2017;30:221-31. doi: 10.1016/j.jht.2017.05.003.
75. Han J, Waddington G, Adams R, Anson J, Liu Y. Assessing proprioception: A critical review of methods. *J Sport Health Sci*. 2016;5:80-90. doi: 10.1016/j.jshs.2014.10.004. Epub 2015 Feb 3.
76. Vafadar AK, Cote JN, Archambault PS. Interrater and intrarater reliability and validity of 3 measurement methods for shoulder-position sense. *J Sport Rehabil*. 2016;25(1):pii: 2014-0309. doi: 10.1123/jsr.2014-0309. Print 2016 Feb 1.
77. Mourcou Q, Fleury A, Diot B, Franco C, Vuillerme N. Mobile phone-based joint angle measurement for functional assessment and rehabilitation of

- proprioception. *Biomed Res Int.* 2015;2015:328142. doi: 10.1155/2015/328142. Epub 2015 Oct 25.
78. Kelley MJ, Shaffer MA, Kuhn JE, et al. Shoulder pain and mobility deficits: adhesive capsulitis. *J Orthop Sports Phys Ther.* 2013;43(5):A1-31. doi: 10.2519/jospt.2013.0302. Epub 2013 Apr 30.
 79. Codsi M, Howe CR. Shoulder conditions: diagnosis and treatment guideline. *Phys Med Rehabil Clin N Am.* 2015;26(3):467-489. doi: 10.1016/j.pmr.2015.04.007.
 80. Wulf G, Lewthwaite R. Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychon Bull Rev.* 2016;23(5):1382-1414.
 81. Clark SE, Ste-Marie DM. The impact of self-as-a-model interventions on children's self-regulation of learning and swimming performance. *J Sports Sci.* 2007;25(5):577-586.
 82. Ste-Marie DM, Vertes K, Rymal AM, Martini R. Feedforward self-modeling enhances skill acquisition in children learning trampoline skills. *Front Psychol.* 2011;2:155. doi: 10.3389/fpsyg.2011.00155. eCollection 2011.
 83. Mattes J. Attentional focus in motor learning, the feldenkrais method, and mindful movement. *Percept Mot Skills.* 2016;123(1):258-276. doi: 10.1177/0031512516661275.
 84. Worsley P, Warner M, Mottram S, et al. Motor control retraining exercises for shoulder impingement: effects on function, muscle activation, and biomechanics in young adults. *J Shoulder Elbow Surg.* 2013;22(4):e11-19. doi: 10.1016/j.jse.2012.06.010. Epub 2012 Sep 1.
 85. Roy JS, Moffet H, Hebert LJ, Lurette R. Effect of motor control and strengthening exercises on shoulder function in persons with impingement syndrome: a single-subject study design. *Man Ther.* 2009;14(2):180-188. doi: 10.1016/j.math.2008.01.010. Epub 2008 Mar 20.
 86. Savoie A, Mercier C, Desmeules F, Fremont P, Roy JS. Effects of a movement training oriented rehabilitation program on symptoms, functional limitations and acromiohumeral distance in individuals with subacromial pain syndrome. *Man Ther.* 2015;20(5):703-708. doi: 10.1016/j.math.2015.04.004. Epub 2015 Apr 14.
 87. Jaggi A, Alexander S. Rehabilitation for shoulder instability - current approaches. *Open Orthop J.* 2017; 11:957-971. doi: 10.2174/1874325001711010957. eCollection 2017.
 88. Moseley GL, Butler DS, Beames TB, Giles TJ. *The Graded Motor Imagery Handbook.* 1st ed. Adelaide, Australia: Noigroup Publications; 2012.
 89. Thieme H, Morkisch N, Rietz C, Dohle C, Borgetto B. The efficacy of movement representation techniques for treatment of limb pain--a systematic review and meta-analysis. *J Pain.* 2016;17(2):167-180. doi: 10.1016/j.jpain.2015.10.015. Epub 2015 Nov 6.
 90. Sanchis MN, Lluch E, Nijs J, Struyf F, Kangasperko M. The role of central sensitization in shoulder pain: A systematic literature review. *Semin Arthritis*
 91. *Rheum.* 2015;44(6):710-716. doi: 10.1016/j.semarthrit.2014.11.002. Epub 2014 Nov 13.
 92. Moseley GL. Graded motor imagery for pathologic pain: a randomized controlled trial. *Neurology.* 2006;67(12):2129-2134.
 93. Coslett HB, Medina J, Kliot D, Burkey A. Mental motor imagery and chronic pain: the foot laterality task. *J Int Neuropsychol Soc.* 2010;16(4):603-612. doi: 10.1017/S1355617710000299. Epub 2010 Apr 12.
 94. Heerkens RJ, Koke AJ, Lötters FJ, Smeets RJ. Motor imagery performance and tactile acuity in patients with complaints of arms, neck and shoulder. *Pain Manag.* 2018;8(4):277-286. doi: 10.2217/pmt-2017-0070. Epub 2018 Jun 1.
 95. Onieva-Zafra MD, Garcia LH, Del Valle MG. Effectiveness of guided imagery relaxation on levels of pain and depression in patients diagnosed with fibromyalgia. *Holist Nurs Pract.* 2015;29(1):13-21. doi: 10.1097/HNP.000000000000062.
 96. Louw A, Puentedura EJ, Reese D, Parker P, Miller T, Mintken PE. Immediate effects of mirror therapy in patients with shoulder pain and decreased range of motion. *Arch Phys Med Rehabil.* 2017;98(10):1941-1947. doi: 10.1016/j.apmr.2017.03.031. Epub 2017 May 5.
 97. Louw A, Zimney K, Puentedura EJ, Diener I. The efficacy of pain neuroscience education on musculoskeletal pain: A systematic review of the literature. *Physiother Theory Pract.* 2016;32(5):332-355. doi: 10.1080/09593985.2016.1194646. Epub 2016 Jun 28.
 98. Moseley GL, Zalucki NM, Wiech K. Tactile discrimination, but not tactile stimulation alone, reduces chronic limb pain. *Pain.* 2008;137(3):600-608.
 99. Caro-Moran E, Diaz-Rodriguez L, Cantarero-Villanueva I, Galiano-Castillo N, Arroyo-Morales M, Fernandez-Lao C. Nerve pressure pain hypersensitivity and upper limb mechanosensitivity in breast cancer survivors: a case-control study. *Pain Med.* 2014;15(10):1715-1723. doi: 10.1111/pme.12567. Epub 2014 Sep 19.
 100. Farrell K, Lampe K. Addressing neurodynamic irritability in a patient with adhesive capsulitis: a case report. *J Man Manip Ther.* 2017;25(1):47-56. doi: 10.1179/2042618614Y.0000000092. Epub 2016 Feb 12.
 101. Hall ML, Mackie AC, Ribeiro DC. Effects of dry needling trigger point therapy in the shoulder region on patients with upper extremity pain and dysfunction: a systematic review with meta-analysis. *Physiotherapy.* 2018;104(2):167-177. doi: 10.1016/j.physio.2017.08.001. Epub 2017 Aug 7.
 102. Calvo-Lobo C, Pacheco-da-Costa S, Martinez-Martinez J, Rodriguez-Sanz D, Cuesta-Alvaro P, Lopez-Lopez D. Dry needling on the infraspinatus latent and active myofascial trigger points in older adults with nonspecific shoulder pain: a randomized clinical trial. *J Geriatr Phys Ther.* 2018;41(1):1-13. doi: 10.1519/JPT.0000000000000079.

102. De Meulemeester KE, Castelein B, Coppieters I, Barbe T, Cools A, Cagnie B. Comparing trigger point dry needling and manual pressure technique for the management of myofascial neck/shoulder pain: a randomized clinical trial. *J Manipulative Physiol Ther.* 2017;40(1):11-20. doi: 10.1016/j.jmpt.2016.10.008.
103. Perez-Palomares S, Olivan-Blazquez B, Perez-Palomares A, et al. Contribution of dry needling to individualized physical therapy treatment of shoulder pain: a randomized clinical trial. *J Orthop Sports Phys Ther.* 2017;47(1):11-20. doi: 10.2519/jospt.2017.6698. Epub 2016 Dec 10.
104. Senbursa G, Baltaci G, Atay OA. The effectiveness of manual therapy in supraspinatus tendinopathy. *Acta Orthop Traumatol Turc.* 2011;45(3):162-167. doi: 10.3944/AOTT.2011.2385.
105. Go SU, Lee BH. Effects of manual therapy on shoulder pain in office workers. *J Phys Ther Sci.* 2016;28(9):2422-2425.
106. Fuentes JP, Armijo Olivo S, Magee DJ, Gross DP. Effectiveness of interferential current therapy in the management of musculoskeletal pain: a systematic review and meta-analysis. *Phys Ther.* 2010;90(9):1219-1238. doi: 10.2522/ptj.20090335. Epub 2010 Jul 22.
107. Barrett E, O'Keeffe M, O'Sullivan K, Lewis J, McCreeesh K. Is thoracic spine posture associated with shoulder pain, range of motion and function? A systematic review. *Man Ther.* 2016;26:38-46. doi: 10.1016/j.math.2016.07.008. Epub 2016 Jul 21.
108. Kalra N, Seitz AL, Boardman ND 3rd, Michener LA. Effect of posture on acromiohumeral distance with arm elevation in subjects with and without rotator cuff disease using ultrasonography. *J Orthop Sports Phys Ther.* 2010;40(10):633-640. doi: 10.2519/jospt.2010.3155.
109. Wassinger CA, Rich D, Cameron N, et al. Cervical & thoracic manipulations: Acute effects upon pain pressure threshold and self-reported pain in experimentally induced shoulder pain. *Man Ther.* 2016;21:227-232. doi: 10.1016/j.math.2015.08.009. Epub 2015 Aug 28.
110. Peek AL, Miller C, Heneghan NR. Thoracic manual therapy in the management of non-specific shoulder pain: a systematic review. *J Man Manip Ther.* 2015;23(4):176-187. doi: 10.1179/2042618615Y.0000000003.
111. Mintken PE, Cleland JA, Carpenter KJ, Bieniek ML, Keirns M, Whitman JM. Some factors predict successful short-term outcomes in individuals with shoulder pain receiving cervicothoracic manipulation: a single-arm trial. *Phys Ther.* 2010;90(1):26-42. doi: 10.2522/ptj.20090095. Epub 2009 Dec 3.
112. Westad C, Mork PJ, Westgaard RH. Firing patterns of low-threshold trapezius motor units in feedback-controlled contractions and vocational motor activities. *Exp Brain Res.* 2004;158(4):465-473.
113. Decicco PV, Fisher MM. The effects of proprioceptive neuromuscular facilitation stretching on shoulder range of motion in overhand athletes. *J Sports Med Phys Fitness.* 2005;45(2):183-187.
114. Gonzalez-Rave JM, Sanchez-Gomez A, Santos-Garcia DJ. Efficacy of two different stretch training programs (passive vs. proprioceptive neuromuscular facilitation) on shoulder and hip range of motion in older people. *J Strength Cond Res.* 2012;26(4):1045-1051. doi: 10.1519/JSC.0b013e31822dd4dd.
115. Rosa DP, Borstad JD, Pogetti LS, Camargo PR. Effects of a stretching protocol for the pectoralis minor on muscle length, function, and scapular kinematics in individuals with and without shoulder pain. *J Hand Ther.* 2017;30(1):20-29. doi: 10.1016/j.jht.2016.06.006. Epub 2016 Oct 18.
116. Sahrmann S. *Movement System Impairment Syndromes of the Extremities, Cervical and Thoracic Spines*. St. Louis, MO: Mosby; 2011.
117. Le Gal J, Begon M, Gillet B, Rogowski I. Effects of self-myofascial release on shoulder function and perception in adolescent tennis players. *J Sport Rehabil.* 2018;27:530-535. doi: 10.1123/jsr.2016-0240. Epub 2018 Sep 30.
118. Han J-T, Lee J-H, Yoon C-H. The mechanical effect of kinesiology tape on rounded shoulder posture in seated male workers: a single-blinded randomized controlled pilot study. *Physiother Theory Pract.* 2015;31:120-125. doi: 10.3109/09593985.2014.960054. Epub 2014 Sep 29.
119. Ozer ST, Karabay D, Yesilyaprak SS. Taping to improve scapular dyskinesis, scapular upward rotation, and pectoralis minor length in overhead athletes. *J Athl Train.* 2018;53:1063-70. doi.org/10.4085/1062-6050-342-17.
120. Morais N, Cruz J. The pectoralis minor muscle and shoulder movement-related impairments and pain: Rationale, assessment and management. *Phys Ther Sport.* 2016;17:1-13. doi: 10.1016/j.ptsp.2015.10.003. Epub 2015 Oct 22.
121. Nagrale AV, Glynn P, Joshi A, Ramteke G. The efficacy of an integrated neuromuscular inhibition technique on upper trapezius trigger points in subjects with non-specific neck pain: a randomized controlled trial. *J Man Manip Ther.* 2010;18(1):37-43. doi: 10.1179/106698110X12595770849605.
122. Eliot DJ. Electromyography of levator scapulae: new findings allow tests of a head stabilization model. *J Manipulative Physiol Ther.* 1996;19(1):19-25.
123. Diederichsen LP, Winther A, Dyhre-Poulsen P, Krogsgaard MR, Norregaard J. The influence of experimentally induced pain on shoulder muscle activity. *Exp Brain Res.* 2009;194(3):329-337. doi: 10.1007/s00221-008-1701-5. Epub 2009 Jan 31.
124. Dutton M. *Dutton's Orthopaedic Examination, Evaluation, and Intervention*. 3rd ed. New York, NY: McGraw Hill Medical; 2012.
125. Turgut E, Duzgun I, Baltaci G. Stretching exercises for subacromial impingement syndrome: effects of 6-week program on shoulder tightness, pain, and disability status. *J Sport Rehabil.* 2018;27(2):132-137. doi: 10.1123/jsr.2016-0182. Epub 2018 Mar 8.

126. Almeida GP, Silveira PF, Rosseto NP, Barbosa G, Ejnisman B, Cohen M. Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. *J Shoulder Elbow Surg.* 2013;22(5):602-607. doi: 10.1016/j.jse.2012.08.027. Epub 2012 Nov 22.
127. Moreno-Perez V, Moreside J, Barbado D, Vera-Garcia FJ. Comparison of shoulder rotation range of motion in professional tennis players with and without history of shoulder pain. *Man Ther.* 2015;20(2):313-318. doi: 10.1016/j.math.2014.10.008. Epub 2014 Oct 19.
128. Mine K, Nakayama T, Milanese S, Grimmer K. Effectiveness of stretching on posterior shoulder tightness and glenohumeral internal-rotation deficit: a systematic review of randomized controlled trials. *J Sport Rehabil.* 2017;26(4):294-305. doi: 10.1123/jsr.2015-0172. Epub 2016 Aug 24.
129. Aldridge R, Stephen Guffey J, Whitehead MT, Head P. The effects of a daily stretching protocol on passive glenohumeral internal rotation in overhead throwing collegiate athletes. *Int J Sports Phys Ther.* 2012;7(4):365-371.
130. Haik MN, Alburquerque-Sendin F, Moreira RF, Pires ED, Camargo PR. Effectiveness of physical therapy treatment of clearly defined subacromial pain: a systematic review of randomised controlled trials. *Br J Sports Med.* 2016;50(18):1124-1134. doi: 10.1136/bjsports-2015-095771. Epub 2016 Jun 10.
131. Watson L, Warby S, Balster S, Lenssen R, Pizzari T. The treatment of multidirectional instability of the shoulder with a rehabilitation program: Part 1. *Shoulder Elbow.* 2016;8(4):271-278. doi: 10.1177/1758573216652086. Epub 2016 Jun 1.
132. Ogston JB, Ludewig PM. Differences in 3-dimensional shoulder kinematics between persons with multidirectional instability and asymptomatic controls. *Am J Sports Med.* 2007;35(8):1361-1370.
133. Molier BI, Van Asseldonk EH, Hermens HJ, Jannink MJ. Nature, timing, frequency and type of augmented feedback; does it influence motor relearning of the hemiparetic arm after stroke? A systematic review. *Disabil Rehabil.* 2010;32(22):1799-1809. doi: 10.3109/09638281003734359.
134. Albuquerque MR, Ugrinowitsch H, Lage GM, Correa UC, Benda RN. Effects of knowledge of results frequency on the learning of generalized motor programs and parameters under conditions of constant practice. *Percept Mot Skills.* 2014;119(1):69-81. doi: 10.2466/23.22.PMS.119c15z0. Epub 2014 Jul 25.
135. Sharma DA, Chevidikunnan MF, Khan FR, Gaowgzech RA. Effectiveness of knowledge of result and knowledge of performance in the learning of a skilled motor activity by healthy young adults. *J Phys Ther Sci.* 2016;28(5):1482-1486. doi: 10.1589/jpts.28.1482. Epub 2016 May 31.
136. Bdaiwi AH, Mackenzie TA, Herrington L, Horsley I, Cools AM. Acromiohumeral distance during neuromuscular electrical stimulation of the lower trapezius and serratus anterior muscles in healthy participants. *J Athl Train.* 2015;50(7):713-718. doi: 10.4085/1062-6050-50.4.03. Epub 2015 May 1.
137. Shumway-Cook A, Woollacott MH. *Motor Control: Theory and Practical Applications.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2000.
138. Menek B, Tarakci D, Algun ZC. The effect of Mulligan mobilization on pain and life quality of patients with Rotator cuff syndrome: A randomized controlled trial. *J Back Musculoskelet Rehabil.* 2019;32(1):171-178. doi: 10.3233/BMR-181230.
139. Doner G, Guven Z, Atalay A, Celiker R. Evaluation of Mulligan's technique for adhesive capsulitis of the shoulder. *J Rehabil Med.* 2013;45(1):87-91. doi: 10.2340/16501977-1064.
140. Watson L, Warby S, Balster S, Lenssen R, Pizzari T. The treatment of multidirectional instability of the shoulder with a rehabilitation programme: Part 2. *Shoulder Elbow.* 2017;9(1):46-53. doi: 10.1177/1758573216652087. Epub 2016 Jul 8.
141. Mendez-Rebolledo G, Gatica-Rojas V, Martinez-Valdes E, Xie HB. The recruitment order of scapular muscles depends on the characteristics of the postural task. *J Electromyogr Kinesiol.* 2016;31:40-47. doi: 10.1016/j.jelekin.2016.09.001. Epub 2016 Sep 7.
142. Rajaratnam BS, Goh J, Kumar PV. Control strategies to re-establish glenohumeral stability after shoulder injury. *BMC Sports Sci Med Rehabil.* 2013;5(1):26. doi: 10.1186/2052-1847-5-26.
143. Day JM, Uhl T. Thickness of the lower trapezius and serratus anterior using ultrasound imaging during a repeated arm lifting task. *Man Ther.* 2013;18(6):588-593. doi: 10.1016/j.math.2013.07.003. Epub 2013 Sep 5.
144. Tucker WS, Armstrong CW, Gribble PA, Timmons MK, Yeasting RA. Scapular muscle activity in overhead athletes with symptoms of secondary shoulder impingement during closed chain exercises. *Arch Phys Med Rehabil.* 2010;91(4):550-556. doi: 10.1016/j.apmr.2009.12.021.
145. Nascimento VY, Torres RJ, Beltrao NB, et al. Shoulder muscle activation levels during exercises with axial and rotational load on stable and unstable surfaces. *J Appl Biomech.* 2017;33(2):118-123. doi: 10.1123/jab.2016-0177. Epub 2016 Oct 13.
146. Park SY, Yoo WG. Activation of the serratus anterior and upper trapezius in a population with winged and tipped scapulae during push-up-plus and diagonal shoulder-elevation. *J Back Musculoskelet Rehabil.* 2015;28(1):7-12.
147. Phadke V, Camargo P, Ludewig P. Scapular and rotator cuff muscle activity during arm elevation: A review of normal function and alterations with shoulder impingement. *Rev Bras Fisioter.* 2009;13(1):1-9.
148. Piraua AL, Pitangui AC, Silva JP, et al. Electromyographic analysis of the serratus anterior and trapezius muscles during push-ups on stable and unstable bases in subjects with scapular dyskinesis.

- J Electromyogr Kinesiol.* 2014;24(5):675-681. doi: 10.1016/j.jelekin.2014.05.009. Epub 2014 Jun 12.
149. Tsuruike M, Ellenbecker T. Serratus anterior and lower trapezius muscle activities during multi-joint isotonic scapular exercises and isometric contractions. *J Athl Train.* 2015;50(2):199-210. doi.org/10.4085/1062-6050-49.3.80.
 150. Yoo WG. Effect of exercise speed and isokinetic feedback on the middle and lower serratus anterior muscles during push-up exercises. *J Phys Ther Sci.* 2014;26(5):645-646. doi: 10.1589/jpts.26.645. Epub 2014 May 29.
 151. Yoo WG. Effect of shoulder flexion angle and exercise resistance on the serratus anterior muscle activity during dynamic hug exercise. *J Phys Ther Sci.* 2016;28(1):278-279. doi: 10.1589/jpts.28.278. Epub 2016 Jan 30.
 152. Seitz AL, Kocher JH, Uhl TL. Immediate effects and short-term retention of multi-modal instruction compared to written only on muscle activity during the prone horizontal abduction exercise in individuals with shoulder pain. *J Electromyogr Kinesiol.* 2014;24(5):666-674. doi: 10.1016/j.jelekin.2014.05.006. Epub 2014 Jun 14.
 153. Maenhout A, Benzoor M, Werin M, Cools A. Scapular muscle activity in a variety of plyometric exercises. *J Electromyogr Kinesiol.* 2016;27:39-45. doi: 10.1016/j.jelekin.2016.01.003. Epub 2016 Jan 28.
 154. Comel JC, Nery RM, Garcia EL, et al. A comparative study on the recruitment of shoulder stabilizing muscles and types of exercises. *J Exerc Rehabil.* 2018;14(2):219-225. doi: 10.12965/jer.1835198.599. eCollection 2018 Apr.
 155. Moreira R, Lial L, Teles Monteiro MG, et al. Diagonal movement of the upper limb produces greater adaptive plasticity than sagittal plane flexion in the shoulder. *Neurosci Lett.* 2017;643:8-15. doi: 10.1016/j.neulet.2017.02.022. Epub 2017 Feb 10.
 156. Demougeot L, Papaxanthis C. Muscle fatigue affects mental simulation of action. *J Neurosci.* 2011;31(29):10712-10720. doi: 10.1523/JNEUROSCI.6032-10.2011.
 157. Schory A, Bidinger E, Wolf J, Murray L. A systematic review of the exercises that produce optimal muscle ratios of the scapular stabilizers in normal shoulders. *Int J Sports Phys Ther.* 2016;11(3):321-336.
 158. Cools AM, Dewitte V, Lanszweert F, et al. Rehabilitation of scapular muscle balance: which exercises to prescribe? *Am J Sports Med.* 2007;35(10):1744-1751.