EVIDENCE… REFERENES… BIBLIOGRAPHY

MSD PATHOPHYSIOLOGY & INJURY MECHANISMS & RISK FACTORS…

1. Barr A, Barbe M. Pathophysiological tissue changes associated with repetitive movement: a review of the evidence. *Phys Ther.* 2002;82(2):173-187.
2. Barr AE, Barbe MF, Clark BD. Work-related musculoskeletal disorders of the hand and wrist: epidemiology, pathophysiology, and sensorimotor changes. *J Orthop Sports Phys Ther.* 2004;34(10):610-627.
3. Byl NN, Merzenich MM, Cheung S, Bedenbaugh P, Ngarajan SS, Jenkins WM. A primate model for studying focal dystonia and repetitive strain injury: effects on the primary motor cortex. *Phys Ther.* 1997;77(3):269-284.
4. Fernandez-de-las-Penas C, Ortega-Santiago R, Ambite-Quesada S, Jimenez-Garcia R, Arroyo-Morales M, Cleland JA. Specific mechanical pain hypersensitivity over peripheral nerve trunks in women with either unilateral epicondylalgia or carpal tunnel syndrome. *J Orthop Sports Phys Ther.* 2010;40(11):751-760.
5. Luopajarvi T. Ergonomic analysis of workplace and postural load. In: Bullock M, ed. *Ergonomics: The Physiotherapist in the Workplace.* New York, NY: Churchill Livingstone; 1990:51-78.
6. Rees JD, Wilson AM, Wolman RL. Current concepts in the management of tendon disorders. *Rheumatology*. 2006;45(5):508-521.
7. Butler DS. Pain mechanisms and peripheral sensitivity. In: *The Sensitive Nervous System*. Adelaide, Australia: Noigroup Publ; 2000:47-71.
8. Strong J, Unruh AM, Wright A, Baxter GD: Neurophysiology of pain and pain modulation. In: *Pain: A textbook for therapists.* London: Elsevier Churchill Livingstone; 2002:43-64.
9. Grozdanovic M. Human activity and musculoskeletal injuries and disorders. *Facta Universitatis Series Medicine and Biology*. 2002;9,(2):150-156.
10. Shacklock M. General neuropathodynamics. In: *Clinical Neurodynamics*. London: Elsevier; 2005:59-72.
11. McPhee B. Musculoskeletal complaints in workers engaged in repetitive work in fixed postures. In: Bullock M, ed. *Ergonomics: The Physiotherapist in the Workplace.* New York, NY: Churchill Livingstone; 1990:101-132.
12. Twoney LT. A rationale for the treatment of back pain and joint pain by manual therapy. *Phys Ther*. 1992;72(12):885-892.
13. Porterfield JA, DeRosa C. *Mechanical Low Back Pain.* Philadephia PA: WB Saunders; 1998: 121-167.
14. Hashimoto T, Nobuhara K, Hamada T. Pathologic evidence of degeneration as a primary cause of rotator cuff tear. *Clin Ortho Relat Res*. 2003;(415):111-120.
15. Blain E, Zhang Y, Aeschlimann D, Caterson B, Duance V. Changes in tendon extracellular matrix compisition with age. *Int J Exp Path*. 2004;85(1):A33-A34.
16. Novak CB. Upper extremity work-related musculoskeletal disorders: a treatment perspective. *J Orthop Sports Phys Ther.* 2004;34(10):628-637.
17. Harms-Ringdahl K, Schuldt K. Neck and shoulder load and load-elicited pain in sitting work postures. In: Bullock M, ed. *Ergonomics: The Physiotherapist in the Workplace.* New York, NY: Churchill Livingstone; 1990:133-147.
18. De-le-Rincon AI, Palacios-Cena D, Fernandez-de-las-Penas C, Cleland JA. Increased forward head posture and restricted cervical range of motion in patients with carpal tunnel syndrome. *J Orthop Sports Phys Ther.* 2009:39(9);658-664.

19. Prizinski F, Brence J. Effective treatment of bilateral carpal tunnel symptoms using cervicothoracic thrust manipulation, neural glides, and periscapular strengthening: a case report. *Orthopaedic Practice.* 2011;23(2):84-88.
20. Lee MJ, LaStayo PC. Pronator syndrome and other nerve compressions that mimic carpal tunnel syndrome. .*J Orthop Sports Phys Ther.* 2004;34(10);601-609.
21. Edgelow P. Neurovascular consequences of cumulative trauma disorders affecting the thoracic outlet. In: Donatelli R, ed. *Physical Therapy of the Shoulder.* New York NY; Churchill Livingstone.1997:153-178.
22. Byng J. Overuse syndromes of the upper limb and the upper limb tension test: a comparison between patients, asymptomatic keyboard workers and asymptomatic non-keyboard workers. *Man Ther*. 1997;2(3):157-164.

ERGO INTERVENTIONS ALONE MAY NOT BE EFFECTIVE

23. Haukka E, Leino-Arjas P, Viikari-Juntura E et al. A randomized controlled trial on whether a participatory ergonomics intervention could prevent musculoskeletal disorders. *Occup Environ Med*. 2008;65(12):849-56.
24. Novak CB. Upper extremity work-related musculoskeletal disorders: a treatment perspective. *J Orthop Sports Phys Ther.* 2004;34(10):628-637.

ERGONOMICS ANALYSIS TOOLS…

25. OSHA 300 log recordkeeping guidelines. http://www.osha.gov/recordkeeping/new-osha300form1-1-04.pdf. Accessed January 26, 2013.
26. Waters TR, Putz-AndersonV, Grag A. *Applications Manual for the Revised NIOSH Lifting Equation.* US Department of Health and Human Services; Public Health Service; NIOSH. 1994.
27. NIOSH Lifting Equation online calculator. http://www.emcins.com/losscontrol/quick_links/employee_safety_health/ergonomicsNIOSH.aspx. Accessed January 26, 2013.
28. Liberty Mutual manual materials handling tables. http://libertymmhtables.libertymutual.com/CM_LMTablesWeb/taskSelection.do?action=initTaskSelection. Accessed January 26, 2013.
29. WISHA Lifting Analysis tool. http://www.lni.wa.gov/wisha/ergo/evaltools/ergocalc.pdf. Accessed January 26, 2013.
30. WISHA Lifting Analysis tool and quick checklist. http://personal.health.usf.edu/tbernard/HollowHills/WISHA_Lifting.pdf. Accessed January 26, 2013:
31. McAtamney L, Corlett EN. RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics.* 1993;24(2):91-99.
32. RULA analysis worksheet. http://ergo.human.cornell.edu/Pub/AHquest/RULAworksheet.pdf. Accessed January 26, 2013.
33. Hignett S, McAtamney L. Rapid entire body assessment (REBA). *Applied Ergonomics.* 2000;31:201-205.
34. REBA analysis worksheet. http://personal.health.usf.edu/tbernard/HollowHills/REBA.pdf. Accessed January 26, 2013.

35. Online lessons on how to perform REBA and RULA. http://www.ncsu.edu/ehs/www99/right/handsMan/office/RULA_REBA_Presentation.pdf. Accessed January 26, 2013.
36. Online lessons on how to perform REBA and RULA. http://www.ergo-plus.com/healthandsafetyblog/ergonomics/reba-assessment-tool-guide/. Accessed January 26, 2013.
37. SAFE Manitoba Ergonomics Risk Factors Checklist. http://safemanitoba.com/uploads/ergonomicriskfactorchecklist.doc This is a download document linked from: http://safemanitoba.com/search/apachesolr_search/ergonomics%20checklist. Accessed January 26, 2013.

WORKER BEHAVIORS, POSTURE HABITS, NON-ERGONOMICS RISK FACTORS…

38. Novak CB. Upper extremity work-related musculoskeletal disorders: a treatment perspective. *J Orthop Sports Phys Ther.* 2004;34(10):628-637.
39. Harms-Ringdahl K, Schuldt K. Neck and shoulder load and load-elicited pain in sitting work postures. In: Bullock M, ed. *Ergonomics: The Physiotherapist in the Workplace.* New York, NY: Churchill Livingstone; 1990:133-147.
40. De-le-Rincon AI, Palacios-Cena D, Fernandez-de-las-Penas C, Cleland JA. Increased forward head posture and restricted cervical range of motion in patients with carpal tunnel syndrome. *J Orthop Sports Phys Ther.* 2009:39(9);658-664.
41. Prizinski F, Brence J. Effective treatment of bilateral carpal tunnel symptoms using cervicothoracic thrust manipulation, neural glides, and periscapular strengthening: a case report. *Orthopaedic Practice.* 2011;23(2):84-88.
42. Lee MJ, LaStayo PC. Pronator syndrome and other nerve compressions that mimic carpal tunnel syndrome. .*J Orthop Sports Phys Ther.* 2004;34(10);601-609.
43. Edgelow P. Neurovascular consequences of cumulative trauma disorders affecting the thoracic outlet. In: Donatelli R, ed. *Physical Therapy of the Shoulder.* New York NY; Churchill Livingstone.1997:153-178.
44. Byng J. Overuse syndromes of the upper limb and the upper limb tension test: a comparison between patients, asymptomatic keyboard workers and asymptomatic non-keyboard workers. *Man Ther*. 1997;2(3):157-164.

POSTURE RISK CONTROL TACTICS (ARM SUPPORTS, SIT-STAND OPTIONS)…

45. Rempel DM, Krause R, Goldberg R, et al. A randomized controlled trial evaluating the effects of two workstation interventions on upper body pain and incidents musculoskeletal disorders among computer operators. *Occup Environ Med.* 2006;63:300-306.
46. Cook C, Burgess-Limerick R, Papalia S. The effect of upper extremity support on upper extremity posture and muscle activity during keyboard use. *Applied Ergonomics*. 2004;35(3):285-92.
47. Cook C, Downse L, Bowman J. Long-term effects of forearm support: computer users working at conventional desks. *Work*. 2008;30(2):107-112.
48. Nag PK, Pal S, Nag A, Vyas H. Influence of arm and wrist support on forearm and back muscle activity in computer keyboard operation. *Applied Ergonomics*. 2008; 40(2):286-291.

49. Lee TH, Huang SM. Effects of wrist rest and forearm support on muscle activity. *Perceptual and Motor Skills*. 2006;103(3):873-878.
50. Hasegawa T, Inoue K, Tsutsue O, Kumashiro M. Effects of a sit-stand schedule on a light repetitive task. *Int J Indust Ergo*. 2001;28(3-4):219-224.

WORKPLACE BACK SCHOOLS

51. Schenk RJ, Doran RL, Stachura JJ. Learning effects of a back education program. *Spine*. 1996;21(19):2183-8; discussion 2189.
52. Holmes W, Lam PY, Elkind P, Pitts K. The effect of body mechanics education on the work performance of fruit warehouse workers. *Work*. 2008;31(4):461-71.
53. Gatty CM, Turner M, Buitendorp DJ, Batman H. The effectiveness of back pain and injury prevention programs in the workplace. *Work*. 2003;20(3):257-266.
54. Daltroy LH, Iverson MD, Larson MG, Lew R, Wright E. A controlled trial of an education program to prevent low back injuries. *NE J Med*. 1997;337(5):323-328.
55. Karas BE, Conrad KM. Back injury prevention in the workplace: an integrative review. *AAOHN*. 1996;44(4):189-96.
56. Linton SJ, Kamwendo K. Low back schools: a critical review. *Phys Ther*. 1987;67:1375-1383.
57. Delitto RS, Rose SJ. An electromyographic analysis of two lifting techniques for squat lifting and lowering. *Phys Ther.* 1992;72(6):438-48
58. Hart DL, Stobbe TJ, Laraiedi M. Effect of lumbar posture on lifting. *Spine*. 1987;12(2):138-145.
59. Versloot JM, Rozeman A, van Son AM, van Akkerveeken PF. The cost-effectiveness of a back school program in industry: a longitudinal controlled field study. *Spine* 1992;17(1):22-7.
60. Heymans MW, van Tulder MW, Esmail R, Bombarier C, Koes BW. Back schools for nonspecific low back pain: a systematic review within the framework of the Cochrane collaboration back review group. *Spine*. 2005;30(19):2153-63.
61. McKenzie RA, May S. *The Lumbar Spine: Mechanical Diagnosis and Therapy.* Waikanae NZ: Spinal Publications; 2003.
62. Cyriax J. *Textbok of Orthopaedic Medicine, Vol 1*. Baltimore Md: Williams and Wilkins;1975:444-451.

WORKPLACE NECK-ARM SCHOOLS

63. Hebert L. Becoming a consultant to industry. *Ortho PT Pract*. 2000;12(20):12-14.
64. Hebert L. Preventive stretching exercises for the workplace, *Ortho PT Pract.* 1999;11(4):11-12.
65. Hebert, L. Analytic focus reduces anxiety over CTD claims, *J Occ Health and Safety*. 1993;62(4):56-62.
66. Melhorn JM. A prospective study for upper extremity cumulative trauma disorders of workers in aircraft manufacturing. *J Occup Enviorn Med*. 1996 Dec;38(12):1264-71.
67. Goodman G, Kovach L, Fisher A, Elsesser E, Bobinski D, Hansen J. Effective interventions for cumulative trauma disorders of the upper extremity in computer users: practice models based on systematic review. *Work*. 2012;42(1):153-72.

WORKPLACE STRETCHING

68. Hebert L. Preventive stretching exercises for the workplace, *Ortho PT Pract.* 1999;11(4):11-12.
69. Twoney LT. A rationale for the treatment of back pain and joint pain by manual therapy. *Phys Ther*. 1992;72(12):885-892.

70. Linton SJ, van Tulder MW. Preventive interventions for back and neck pain problems. *Spine*. 2001;26(7):778-787.
71. Moore TM. A workplace stretching program. Physiologic and perception measurements before and after participation. *AAOHN J*. 1998 Dec;46(12):563-8.
72. Fenety A, Walker JM. Short-term effects of workstation exercises on musculoskeletal discomfort and postural changes in seated video display unit workers. *Phys Ther*. 2002;82(6):578-589.
73. Jepson JR, Thomsen G. Prevention of upper limb symptoms and signs of nerve afflictions in computer operators: the effects of intervention by stretching. *Journal of Occupational Medicine and Toxicology*. 2008;3(1).
74. daCosta BR, Vieira ER. Stretching to reduce work-related musculoskeletal disorders: a systematic review. *J Rehabil Med.* 2008;40:321-328.
75. Marangoni AH. Effects of intermittent stretching exercises at work on musculoskeletal pain associated with the use of a personal computer and the influence of media on outcomes. *Work*. 2010;36(1):27-37.
76. Barredo RD, Mahorn K. The effects of exercise and rest breaks on musculoskeletal discomfort during computer tasks: an evidence-based perspective. *J Phys Ther Sci*. 2007;19(2):151-163.
77. OSHA recommendations for computer work MSD prevention. http://www.osha.gov/SLTC/etools/computerworkstations/workprocess.html#Prolonged. Accessed February 6, 2013.
78. Marklin RW, Simoneau GC. Design features of alternative computer keyboards: a review of experimental data. *J Orthop Sports Phys Ther.*. 2004;34(10):638-649.
79. Hess JA, Hecker S. Workplace stretching programs: the rest of the story. *Appl Occup Environ Hyg*. 2003;18(5):331-8.
80. Balci R, Aghazadeh F:The effects of work-rest schedules and type of task on the discomfort and performance of VDT users. *Ergonomics*. 2003;46(5):455-65.

IMPORTANT JOURNAL SPECIAL ISSUE… JOSPT OCT 2004:

MacDermid J, Doherty T: Clinical & Electrodiagnostic Testing of carpal Tunnel Syndrome. JOSPT 2004 Oct.
Review of various simple non-invasive diagnostic testing for CTS, with correlations to electrodiagnostic testing. Includes valid testing per history, sensory screening, provocation tests, NVC-EMG.

Michlovitz S: Conservative Interventions for CTS. JOSPT, 2004 Oct.
Review of current PT approaches to clinical management of CTS.

Lee M, LaStayo P: Pronator Syndrome and Other Nerve Compressions That Mimic CTS. JOSPT, 2004 Oct.
Differential assessment of median nerve compressions of the upper extremity proximal to the wrist, mimicking CTS, along with treatment approaches for these.

Barr A, et al: Work-Related Musculoskeletal Disorders of the Hand and Wrist," JOSPT, 2004 Oct.
Extensive review of research on MSD pathophysiology, diagnosis, epidemiology. Of particular note is description of pathophysiology, especially describing histochemical changes that can trigger systemic inflammatory responses. Cytokines are released from local inflammatory sites may trigger systemic inflammatory responses, thus causing tendinitis symptoms to spreading to other sites. Of equal interest is the motor behavior degradation that can occur with repetitive motion tasks, causing loss of motor control and a resulting loss of coordination and movement efficiency that may increase work damage. This may be the result of changes at the brain where repetitive movement causes degradation of motor cortex, distorting motor control. This is reorganization of CNS control of movement.

Novak C, "Upper Extremity Work-Related Musculoskeletal Disorders: a Treatment Perspective," JOSPT, OCT 2004
This is an excellent discussion of various important pathomechanics of MSD. Of particular interest is the prevalence of multi-level neurovascular compressions (double-crush) {{a critical issue in prevention tactics where we address proximal posture risks to reduce distal repetitive motion problems}}. Static postures, particularly at the neck are also described {{another critical issue in prevention tactics where we address proximal posture risks to reduce distal repetitive motion problems}}. Posture risks at various articulations are described. Treatment approaches are also well-described in this paper.

MORE IMPORTANT REFERENCES WITH ABSTRACTS & COMMENTS….

COSTS & EPIDEMIOLOGY

Lou, Pietbrobon, et al: Estimates and patterns of direct health care expenditures among individuals with back pain in the Untied States. Spine 2004; 1: 79-86.
It is estimated that over the course of an average lifetime, 80 percent of Americans will suffer at least one episode of back pain.

Maetzel A, Li L. The economic burden of low back pain: a review of studies published between 1996 and 2001. Best Pract Res Cli Rheumatol 2002; 16:23-30.
Low back pain results in approximately 149 million lost work days annually, with 2/3 of these caused by occupational injury and an annual lost productivity loss of $28 billion.

Pai S, Sundaram L. Low back pain: an economic assessment in the United States. Orthop Clin North Am 2004; 35: 1-5. …Estimated annual cost for low back pain is $20-50 billion.

Bernacki E. Factors influencing the costs of workers' compensation. Clin Occup Environ Med 2004; 4: v-vi, 249-57. California's Worker Compensation data fro 1993 to 2000 showed that indemnity costs increased eightfold when there is legal involvement.

EXERCISES & REST BREAKS

De Vera Barredo R, Mahon K: The effects of exercise and rest breaks on musculoskeletal discomfort during computer tasks: an evidence based perspective. J Phys Ther Sci, 2007, vol 19, no 2: 151-163.
A review of research evidence on effects of exercise and rest breaks on musculoskeletal discomfort during computer work found that evidence supports use of rest breaks and exercise breaks to reduce discomfort. The evidence, in aggregate, suggests no additional benefits of exercises over rest breaks. This review identified widespread problems with research design, internal validity, statistical analyses, dropout rates and poor subject compliance. This serves to illustrate the potential value of rest breaks and exercise breaks but identifies problems with the research in allowing us to reach valid conclusions. This article is also an excellent demonstration of how to assess the value of research according to levels of evidence and internal validity.

Fenety A, Walker JM: Sort-term effects of workstation exercises on musculoskeletal discomfort and postural changes in seated video display unit workers. Phys Ther, 2002, 82: 578-589.
Authors examined short term effects of an exercise program on eleven subjects, involving an exercise break every 30 minutes. Exercises done by video display unit operators resulted in short-term decrease in both musculoskeletal discomfort and postural immobility. This is a non-randomized trial where participants acted as their own controls, resulting in evidence level IV with moderate internal validity.

Saltzman A: Computer user perception of the effectiveness of exercise mini-breaks. In: Proceedings of the Silicon Valley Ergonomics Conference and Exposition. Silicon Valley, CA, 1998, 147-151.
Authors examined effects of an ergonomics exercise software program of frequent short stretch breaks. Participants reported stretch breaks were effective in reducing workplace discomfort. 23 percent of participants reported increased productivity. 34 percent of participants dropped out of the study. This study is level V evidence with weak internal validity.

Thompson D: Effects of exercise breaks on musculoskeletal strain among data entry operators: a case study. In: Promoting Health and Productivity in the Computerized Office: Models of Successful Ergonomics Intervention. Taylor and Francis, 1990, 118-127.
Employees were asked to perform five-minute exercise sessions during their two regular break periods. Operators reported reduced discomfort and generally improved physical condition. There were no Worker Compensation claims for one year into the program. Productivity had increased by 25 percent during the first four months of the program. Level of evidence is V, with weak internal validity.

Linton S, van Tulder M: Preventive interventions for back and neck pain problems. Spine, 2001 vol 26, no 7: 778-787.
A review of 27 controlled trials demonstrated back schools to be ineffective for prevention, with exercises being the only effective preventive intervention.

Karas B, Conrad K: Back injury prevention in the workplace: an integrative review. AAOHN J, 1996; 44(4): 189-96.
Review of 15 experimental and quasi-experimental studies showed some positive evidence for back belts, back schools, stretching programs, and educational classes. Back schools and stretching programs were studied more frequently and showed the greater proportion of positive results.

Moore T: A workplace stretching program. Physiologic and perception measurements before and after participation. AAOHN J, 1998, 46(12): 563-8.
Participants who completed a structured stretching program had zero occurrences of MSD during the two-month period. There was statistically significant improvements in flexibility and the Fox Self Perception Profile, suggesting that flexibility exercises may reduce workplace MSD.

Silverstein B, Armstrong T, et al: Can in-plant exercise control musculoskeletal symptoms? J Occup Med, 1988, 30 (12): 923-927.
After one year of an on-the-job exercise program to control musculoskeletal symptoms in the neck and upper limb, there were no statistically significant differences in localized postural discomfort scores or in the proportion of those whose discomfort decreased based on exercise participation. Although no clear reduction in discomfort was achieved by the exercise program alone, at least 67 percent of respondents who participated in the exercise program reported that the program made them feel better.

Galinsky T, et al: Supplementary breaks and stretching exercises for data entry operators: a follow-up field study. Am J Indust Med. 2008, 30(7); 519-527
Workers in the supplementary breaks group scored significantly lower in discomfort and maintained output despite extra break periods. The group that was to add exercises to their break period reported only 25 percent exercise compliance during break periods, preventing valid assessment of stretching effects.

Balci R, Aghazadeh F: The effect of work-rest schedules and types of task on the discomfort and performance of VDT users. Ergonomics, 2003, 46: 455-465.
and
Balci R, Aghazadeh F: Effects of exercise breaks on performance, muscular load, and perceived discomfort in data entry and cognitive tasks. Computers & Industrial Engineering, 2004, 46(3):399-411.
Comparing various work time versus rest time periods revealed that very brief very frequent micro-breaks resulted in less discomfort and higher accuracy and productivity than did longer work periods with longer breaks. This study was level II evidence with strong internal validity.

Hess J, Hecker S: Workplace stretching programs: the rest of the story. Appl Occup Envir Hyg, 2003; 18(5): 331-8.
Several studies are examined and analyzed in detail, describing positive and negative findings among a variety of studies and exercise approaches. One study review included flexibility program for firefighters. Showing no significant reduction in incidence of LBI, but injury costs significantly reduced ($85,372 for stretch group versus $235,131 for control group) from Hilyer 1990.

Hilyer J, et al: A flexibility intervention to reduce the incidence and severity of joint injuries among municipal firefighters. J Occup Med 1990, 32(7): 631-637.
A flexibility program for firefighters showed no significant reduction in incidence of musculoskeletal injury, but total injury costs significantly reduced ($85,372 for stretch group versus $235,131 for control group)

SIT-STAND

Hasegawa T, et al: Effects of a sit-stand on a light repetitive task. Int J Indust Ergo, 2001, 28 (3-4): 219-224.
Subjects performed light repetitive tasks in sitting and standing. More frequent switches between postures resulted in better work performance and less fatigue that with less frequent switch.

BACK SCHOOLS

Schenk R, Doran R, Stachura J: Learning effects of a back education program. Spine 1996; Oct 1; 21(19): 2183-2189.
The American Back School was compared to a video education group and a control group. Learning effect was assessed by examining gains in post-test results. No differences in post-test comparisons were seen in control and video groups. Significant differences were seen in the back school group at the .001 level, indicating that back

school is an effective intervention for influencing lifting posture and conveying information on spinal mechanics and lifting technique. Additionally, video training may not be an effective prevention intervention.

Heymans M, van Tulder M, et al: Back schools for nonspecific low back pain: a systematic review within the framework of the Cochran Collaboration Back Review Group. Spine. 2005; 30(19): 2153-63.
There is moderate evidence suggesting back schools in an occupational setting reduce pain and improve function and return-to-work status.

Karas B, Conrad K: Back injury prevention in the workplace: an integrative review. AAOHN J, 1996; 44(4): 189-96.
Review of 15 experimental and quasi-experimental studies showed some positive evidence for back belts, back schools, stretching programs, and educational classes. Back schools and stretching programs were studied more frequently and showed the greater proportion of positive results.

Gatty C, et al: The effectiveness of back pain and injury prevention programs in the workplace. Work 2003; 20(3): 257-66.
Review of nine studies showed that positive outcomes were associated with studies reporting high compliance that used job-specific and individualized/small group education and training approaches.

van Poppel M, et al: An update of a systematic review of controlled clinical trials on the primary prevention of back pain in the workplace. Occup Med (Lond), 2004; 54(5): 345-52.
There is no evidence for effectiveness of back supports or education in primary prevention of LBP. There is limited evidence of moderate efficacy or exercise.

LIFTING WITH LORDOSIS

Hart D, Stobbe T, Jaraiedi M: Effects of lumbar posture on lifting. Spine 12:138-145, 1987.
Describes the advantages of lifting with lumbar spine positioned in a lordotic loading position versus in a kyphotic position (posterior pelvic tilt). They noted the advantage of lordotic lifting creating higher protective muscle contraction, as evidenced by EMG, providing a protective muscle action to counter flexion moments on the disc. Also, flexion moments were higher in the kyphotic lifting position and lower in lordotic lifting position.

Delitto R, Rose S, Apts D: Phys Ther 1987; 67(9):1329-34.
This study examined the effects of two different alignments of the lumbar spine on electromyographic activity of the erector spinae (ES) and oblique abdominal (OA) muscles during squat lifting. Nineteen healthy subjects (8 men, 11 women) participated in this study. Each subject performed squat lifts both with the lumbar spine aligned in "back-bowed-in" (BBI), or normal, lordosis and with the lumbar spine aligned in "back-bowed-out" (BBO), or relatively less, lordosis. Based on total duration, the lift was divided into two equal phases. EMG activity of each muscle was quantified for each half of the lift and normalized to the total EMG produced by the muscle during a maximal voluntary isometric contraction. A three-way analysis of variance for repeated measures was used to analyze the effects of position of the lumbar spine, timing, and load on the amount of EMG activity during lifting. For all loads, ES muscle activity was greater during the first half of the BBI lift, whereas OA muscle activity was greater during the first half of the lift, regardless of the lifting style (p less than .01). The greater ES and OA muscle activity occurring during the crucial initial period in the BBI lift may provide the best protection for the lumbar spine.

Bazrgari B, Shirazi-Adi A, Arjimand N: Analaysis of squat and stoop lifting : muscle forces and internal spinal loads. Eur Spine J 2007; May; 16)5):687-99.
Findings advocate for squat lifting over stoop lifting as the technique of choice in reducing net moments, muscle forces and internal spinal loads (moment, compression, shear forces).

Hickey D, et al: Relation between the structure of the annulus fibrosus and function and failure of the intervertebral disc. Spine 1985; 5(2):106-114.
Annulus fibers have the same mechanical properties as tendon fibers, per tolerance to stretch and strain. Failure of the annulus is most likely to fail during forward bending loads and during torsion loads, whereas compression is more likely to cause end-plate failure.

POSTURE

Gerr F, et al: A randomized controlled trial of postural interventions for prevention of musculoskeletal symptoms among computer workers. Occup Environ Med. 2005 Jul; 62(7): 478-87.
This study assigned two intervention groups each a work posture to maintain during computer work, plus a control group with no posture intervention. Results showed no significant differences in the incidence of musculoskeletal symptoms among the three groups, suggesting that the two postural interventions are ineffective at reducing

symptoms. {{Lauren adds: I would suggest that this may support the hypothesis that it is not the position that leads to posture-related pain but, rather, the time spent in a sustained position that leads to symptoms. Position may matter less than time spent in the position.}}

Melhorn J: A prospective study for upper extremity cumulative trauma disorders of workers in aircraft manufacturing. J Occup Environ Med, 1996; 38(12): 1264-71
8000 employees underwent prospective study in a four-way experimental design to assess several interventions showed that only posture training had a beneficial risk reduction. Combination of posture training and exercise had beneficial effect for two of the groups.

UE SUPPORT

Nag P, et al: Influence of arm and wrist support on forearm and back muscle activity in computer keyboard operation. Appl Ergo. 2009; 40(2): 286-291,
Study examined muscle activity while using a wrist rest, forearm support and floating (unsupported) upper extremity work posture during keyboard work. Wrist rest showed mixed reductions in muscle activity, while forearm support showed widespread reduction in muscle activity compared to forearms unsupported.

Conlon C, Krause N, Rempel D: A randomized controlled trial evaluating an alternative mouse and forearm support on upper body discomfort and musculoskeletal disorders among engineers. Occup Environ Med. 2008 May; 65(5): 311-8.
In engineers using computers more than 20 hours per week, a forearm support board may reduce right upper extremity computer use.

Remple D, et al: A randomized controlled trial evaluating the effects of two workstation interventions on upper body pain and incident musculoskeletal disorders among computer operators. Occup Environ Med. 2006 May; 63(5): 300-6.
Comparing ergonomics training only with training plus computer trackball with training plus forearm support revealed that training plus forearm support was effective in preventing upper body MSD among call center employees.

ERGONOMICS INTERVENTIONS

Haukka E, et al: A randomized controlled trial on whether a participatory ergonomics intervention could prevent musculoskeletal disorders. Occup Environ Med. 2008 Dec; 65(12): 849-56.
A cluster randomized trial of 504 kitchen workers in 119 workplaces over 11-14 month period with 402 ergonomics changes implemented revealed no systematic differences in any outcome variable between intervention group and control group. There was no reduction in perceived physical workload or MSD among these workers.

Karsh B, Moro F, Smith M: The efficacy of workplace ergonomic interventions to control musculoskeletal disorders: a critical analysis of peer-reviewed literature. Theor Iss Ergo Sci, 2001, vol 2, no 1: 23-96.
An analysis of 101 peer-reviewed studies examining the efficacy of a range of workplace ergonomic interventions concluded that the most effective interventions were multiple-component interventions. Of the studies considered 84 percent found some positive results, although most had mixed outcomes. Only 32 percent of the studies used experimental or quasi-experimental designs.

PATHOLOGENESIS

Byng J: Overuse syndromes of the upper limb and the upper limb tension test: a comparison between patients, asymptomatic keyboard workers and asymptomatic non-keyboard workers. Man Ther 1997, 2: 157-164
The ULTT was positive in 100 percent of the patient group, supporting the hypothesis that the pathology of occupational upper limb overuse is neurogenic in origin. Furthermore, the asymptomatic keyboard users (intended to be a control subgroup) also had a significantly higher positive ULTT compared to asymptomatic non-keyboard users (the other control subgroup).

Porterfield J, DeRosa C: Mechanical Low Back Pain: Perspectives in Functional Anatomy. 1998; W.B. Saunders.
Describes functional anatomy, biomechanics, pathomechanics, degenerative changes at the lower spine at the zygoapophyseal joints, intervertebral discs and sacroiliac joint.

Riley G, et al: Tendon degeneration and chronic shoulder pain: changes in collagen composition on the human rotator cuff tendons in rotator cuff tendinitis. Ann Rheum Dis. 1994; 53(6): 359-66
Degenerated tendons show changes consistent with repeated minor injury and fiber damage consistent with reduced vascular perfusion, tissue hypoxia and influence of cytokines, weakening the tendon.

Lundborg G, Dahlin L: Anatomy, function, and pathophysiology of peripheral nerves and nerve compression. Hand Clin 1996; 12(2):185-93.
The clinical stages of nerve compression lesions can be related to changes in intraneural microcirculation and nerve fiber structure, alterations in vascular permeability and subsequent formation of edema. The double crush and reverse double crush syndromes are related to disturbances in axonal transport induced by compression, followed by morphological and functional changes in nerve cell bodies.

Edgelow P: Ch.6; Neurovascular consequences of cumulative trauma disorders affecting the thoracic outlet: a patient-centered approach. In Donatelli R (ed): Physical Therapy of the Shoulder; 1997; Churchill-Livingstone.
Comprehensive description of pathomechanics and pathophysiology of thoracic outlet compression.

ON-SITE PT

Sadi J, et al: A 13-year study of musculoskeletal disorders treated in an autoplant , on-site physiotherapy clinic. J Occup Rehabil. 2007; 17(4): 610-22.
On-site physiotherapy services can provide early cost-effective management of MSD in the automotive sector.

Rothstein, et al: The hypothesis-oriented algorithm for clinicians II (HOAC II): a guide for patient management. Phys Ther 2003, 83 (5): 455-47.
Describes the clinical decision-making process defined by HOAC-II as a structured process of patient evaluation, problem-identification, goal-setting, intervention selection, and outcomes assessment.

BACK BELTS

Kraus J, et al: Reduction of acute low back injuries by use of back supports. Intl J Occ Envir Hlth, 1996; 2(3).
The study was sponsored by UCLA School of Public Health and the Southern California Injury Prevention Research Center. The study of 36,000 employees at 31 Home Depot stores in California encompassing 101,000,000 work hours revealed a decrease of 34% in low back injuries following a mandatory policy on use of back supports among employees. Favorable effects were seen in both genders, young and old, new or experienced workers, low lifting intensity and high lifting intensity jobs. The study provides evidence that proper use of back supports as part of a comprehensive back injury prevention program may be effective in reducing back injuries.

Kraus J, et al: Back supports and low back injuries: a second visit with the Home Depot cohort study data. Intl J Occ Envir Hlth, 1999; 5: 9-13.
This paper revisits data for the study suggesting favorable low back injury prevention effects of wear back supports in the workplace, in response to letters to the Journal editor questioning the study's findings. The issues were examined and answered, supporting the validity of the findings.

Warren L, et al: Effects of soft lumbar support belt on abdominal oblique muscle activity in nonimpaired adults during squat lifting. JOSPT 2001; 31.
Wearing a soft lumbar support during squat lifting significantly decreased activity of abdominal obliques. This study shows back belts reduce muscle activity and this should be consistent with decreased loads on the spine, likely due to increased intra-abdominal pressure. This is consistent with other studies that, taken together, demonstrate the both abdominal and back muscles produce less force during lifting with a back support. Decreased coactivation of the muscles around the spine suggests that spinal compressive forces are decreased. Loads on the spine during lifting tasks are positively correlated with increased muscle activity. Intra-abdominal pressure is significantly increased with wearing a back belt during lifting. Increased intra-abdominal pressure is believed to result in decompression of the spine during loading and decreased load on spinal muscles. There is also an increased recruitment of quadriceps muscle action during lifting with back belts, suggesting they encourage improved lifting technique. This paper mentions numerous studies in its text and its bibliography that add support to the hypothesis of the authors.

Van Duijvvenbode, et al: Lumbar supports for prevention and treatment of low back pain. Cochrane Database Syst Rev. 2008; (2):CD001823.
There is moderate evidence that back supports are not more effective than no intervention or training. There is conflicting evidence of their effectiveness when combined with other interventions.

Van Tulder M, et al: Lumbar supports for prevention and treatment of low back pain. Cochrane Database Syst Rev. 2007; (2):CD001823.
There is moderate evidence that back supports are not more effective than no intervention or training. There is conflicting evidence of their effectiveness when combined with other interventions. Authors also point out that

quality of the research reviewed was poor and that one essential issue in the research was inadequate subject compliance

Ammendolia C, et al: Back belt use for prevention of occupational low back pain: a systematic review. J Manip Phys Ther. 2005;28(2): 128-34.
As of 2003, conflicting evidence and the lack of high quality trials imply there is no conclusive evidence to support the use of back belts to reduce lost time from occupational LBP.

Butler, David: THE SENSITIVE NERVOUS SYSTEM; Noigroup Publ, Adelaide, Australia, 2000.
The is an excellent text on the neurophysiology of pain, nerve mobility and adverse neural tension, neurovascular entrapment, AIGS, double crush, central excitation, upregulation of pain, and other issues that closely relate to extremity pain syndromes, particularly those involved with work disorders. Excellent description of underlying issues important to dealing with injured workers. Addresses mobilization of the peripheral nervous system, which may be a part of the stretching tactics we may consider for the workplace.

IMPORTANT TEXT:
Bullock M, ed.: Ergonomics: The Physiotherapist in the Workplace, Churchill-Livingstone, 1991.
pp 214-215 and 228-229. This text describes the role of the physical therapist as highly qualified industry resource for ergonomics. The physical therapist is described as providing a valuable mix of musculoskeletal medical training with human biomechanics and physics of movement and posture as the basic science foundation of this profession. Most large industry settings in Europe employ on-site physical therapists as their ergonomics resource (in contrast with US industry which relies primarily on engineers.) In Scandinavian countries ergonomics is chiefly the domain of physical therapists.
pp 52-53: Posture workload is described as a primary risk for CTD. Static muscle contraction reduces circulatory irrigation to muscle, decreasing oxygen and creating metabolic wastes accumulation in the tissues, leading to pain and tissue hardening. Muscle posture work should not tolerate more than 5-6% of MVC in work conditions exceeding one hour. Rapid repetitive motion and high accuracy demands create increased background tensions in working muscles and tendons, as do noise and cold, creating similar stresses as seen in excessive posture load demands and high MVC. Similar stresses are seen when repetitive loading exceeds 50% of MVC and peak loading exceeds 75% of MVC. Similar stresses are seen in extreme positions and sudden jerky motions.
pp 108-115: Posture load is described as a severe risk, particularly in the presence of short rest breaks. Static posture loads with short rests is a strong risk. Posture load is a risk especially when posture is awkward or needed to manipulate tools distally. Speed of repetition increases static posture loads (Waersted 1986). Forward head posture is seen as a pain source in many static posture jobs according to one study, suggesting pain is a result of mechanical deformation of passive tissues (Harms-Ringdahl 1986). Static loading is identified as stress causing fatigue and reduction in blood flow at a time when wastes are increasing and oxygen demands are increasing (IBID). VDT work is discussed in this context, with up to 95% demonstrating symptoms (Bjorksten 1984). Management of this risk calls for improving posture habits, early symptom reporting, redeployment of work, and task alternation. Fatigue is the precursor to musculoskeletal pain problems. Repetitive light tasks produced significant changes in EMG and serum creatine kinase (SCK) in local muscles. These changes were not seen in heavy aerobic tasks (Hagberg and Jonsson 1982, 1984). The quality and frequency of rest affects the ability of muscles to recover (Rhomert).
pp 134-143: Forward head posture produces stress through muscles posture load and passive tissue loads at ROM extremes, where EMG may be quiet. Posture loads at neck and shoulder are affected by motions, postures and loads in the arms and hands. Precision, speed, psychological stresses all increased muscle posture loads. Neutral upright head posture uses approximately 2% of MVC; slightly flexed uses 10%; much flexed posture uses 17% of MVC. Trapezius fatigue is reached where MVC is at 2-5% for more than an hour. This load is greatly increased with arm flexion or abduction. Flexion was defined as lower cervical flexion with some compensatory extension at upper cervical, a protracted head posture over the shoulders (Harms-Ringdahl and Schuldt 1988). Work with arms unsupported greatly accelerates fatigue. The more they are elevated, the more fatigue changes are seen spreading from the upper traps to the lower traps, thoracic erector spinae, rhomboids and glenohumeral muscles. Symptoms are related to time spent in forward postures, shoulder elevation, and total duration of arm activity. Endurance also depended upon the worker's physical condition. Continuous arm activity entails no return to zero activity, so there is no relaxation of neck and shoulder muscles. Rather, movement is superimposed on static contractions. This is in light of the obstruction in perfusion of these working tissues (Schuldt, Jonsson, Christensen). The use of micro-pause loading breaks for only a few seconds are important to preserve comfort and work performance through the work day. When the hands and arms are supported during work activity, there is less pain in the neck and shoulder region(Hunting, 1981). Elbow support, properly designed, reduced activity in the traps, rhomboids, and erector spinae in both erect and flexed head positions among assembly workers (Schuldt, 1987).

Barr A, Barbe, M: Pathophysiological Tissues Changes Associated with Repetitive Movement: A Review of the Evidence. Phys Ther. 2002 February: 82(2): 173-187.

This article presents several key considerations defining MSD pathophysiological mechanisms taken from extensive literature review, particularly among animal studies describing neuromusculoskeletal responses to repetitive or sustained loading demands. Key points include:

CELLULAR CHANGES:

Muscle tissue biopsies of humans with hand overuse symptoms showed histological and muscle fiber structure changes consistent with denervation or ischemic loss of type II fibers with hypertrophy of type I fibers. Upper trapezius samples showed changes consistent with hypoxia and reduced blood flow. Cell membrane damage releases intracellular factors that stimulate infiltration of lymphocytes and macrophages. These processes stimulate regreneration, or scarring if that damage is ongoing. In tendons this can result in fibroblast proliferation leading to fibrosis and collagen dysplasia within the extracellular matrix. Ongoing mechanical or metabolic stress such as hypoxia, ischemia or inflammation leads to release of heat shock proteins (HSP) by cells such as neurons, glia, fibroblasts and muscle cells. This is a healing protective response whereby these HSP restore denatured proteins. HSP are stimulated by ischemia or tears in cell membranes releasing cytokines, mediators of inflammation, cell proliferation and regeneration. These mediate proliferation of macrophages and fibroblasts. The phagocytic action of the macrophages can further increase damage and release more cytokines, thus creating a vicious cycle of chronic inflammation.

CNS CORD CHANGES:

Chronic pain can lead to neuroplastic changes in CNS and PNS. Sustained nociceptive afferent bombardment can increase release of excitatory neurotransmitters glutamate and substance P in the dorsal horn. These can activate and potentiate synapse activity both presynaptically and postsynaptically. This can also alter genetic expression in neurons to upregulate receptor sites. The end result is hyeralgesia (increased sensitivity to nociception) and allodonia (non-painful stimuli felt as pain). Clinicians often mistake this process as "symptom magnification" or psychological complications. Nerve constriction peripherally due to repetitive or sustained mechanical compression can also cause neuroplastic changes in the dorsal root ganglion that can increase nociception transmission.

CNS CORTEX CHANGES:

Repetitive tasks can induce changes in cerebral cortex, particularly de-differentiation of cerebral cortex representation of the hand. This is induced by constrained and repeated motions at the upper limb. Loss of specific hand field representation of the cortex causes loss of coordination and changes in movement behaviors toward less efficient motor control. This loss of movement efficiency increase fatigue and pain risks during repetitive tasks. This is maladaptive movement behavior. It may be that this motor control degradation precedes the onset of pain and may even precipitate it.

SYSTEMIC INFLAMMATORY REACTION:

Animal studies reveal increased cellular chemical changes: HSP-72, COX2, and macrophage infiltration at levels 1000 times above baseline. PLUS, these biochemical changes were seen also in the non-moving control limbs, suggesting a systemic inflammatory response to the high repetition low load tasks in the experiment. This suggests that repetitive task work can lead to not only local inflammatory reactions at the exposure site, but also leads to a wider systemic inflammatory response as well as neurological reorganization (neuroplasticity) centrally at the spinal cord, increasing nociception, and at the cerebral cortex, causing motor control degradation.

<u>USEFUL WEB SITES:</u>

http://www.emcins.com/lc/niosh.htm
Automated online NIOSH Lifting Equation calculator

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=federal_register&p_id=16305
This is the entire OSHA Ergonomic Final Rule; (29 CFR 1910.900, November 14, 2000).
Federal Register #: 64:65768-66078

http://personal.health.usf.edu/tbernard/HollowHills/WISHA_WMSD_Checklist.pdf
Washington State MSD hazards checklist format

http://personal.health.usf.edu/tbernard/HollowHills/WISHA_Lifting.pdf
Washington State lifting hazards calculator

http://www.ergo.human.cornell.edu/
Cornell University web site of numerous ergonomics research, guides, analysis tools