# Appendix 1: Search Strategy

MEDLINE

1. intervertebral disc degeneration/ or intervertebral disc displacement/

2. ((spine or spinal or vertebr\* or interverteb\* or disk\* or disc\*) adj3 (degenerat\* or displace\* or injur\* or damage\* or herniat\*)).mp.

3. Lumbago.mp. or exp Low Back Pain/

4. back ache.mp. or exp Back Pain/

5. 1 or 2 or 3 or 4

6. (workload or workplace or work-related or worker\* or employee\* or job related or occupational or industrial).mp.

7. exp Occupations/

8. exp Physical Exertion/ or Occupation\* load.mp.

9. exp "Moving and Lifting Patients"/ or lifting.mp. or exp Lifting/

10. exp Torque/

11. weight bearing.mp. or exp Weight-Bearing/

12. Mechanical stress.mp. or exp Stress, Mechanical/

13. exp Vibration/ or Body vibration\*.mp.

14. whole body vibration\*.mp.

15. 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14

16. 5 and 15

17. ra.fs. or imag\*.mp. or x-ray\*.mp. or us.fs. or ultrasound.mp. or tomograph\*.mp. or ct.mp. or scan\*.mp. or radiolog\*.mp. or radiograph\*.mp. or mri.mp.

18. 16 and 17

EMBASE

1. exp intervertebral disk degeneration/

2. ((spine or spinal or vertebr\* or interverteb\* or disk\* or disc\*) adj3 (degenerat\* or displace\* or injur\* or damage\* or herniat\*)).mp.

3. Lumbago.mp. or exp low back pain/

4. back ache.mp. or exp backache/

5. 1 or 2 or 3 or 4

6. exp occupation/ or exp occupational health/ or exp workload/ or exp occupational exposure/ or Occupation\* load.mp. or exp occupational disease/

7. exp whole body vibration/ or Vibrations.mp. or exp vibration/

8. lifting.mp. or exp biomechanics/

9. torque.mp. or exp torque/

10. exp mechanical torsion/ or exp torsion/ or torsion.mp.

11. weight bearing.mp. or exp weight bearing/

12. Mechanical stress.mp. or exp mechanical stress/

13. 6 or 7 or 8 or 9 or 10 or 11 or 12

14. 5 and 13

15. (imag\* or x-ray\* or radiolog\* or radiograph\* or ultrasound or tomograph\* or ct or mri or scan\*).mp. [mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]

16. 14 and 15

CINAHL until October 2015

S1 "Occupation" OR "Occupation\*" Or "Occupation\* Load" OR "Lifting" OR "Torque" Or "weight bearing" Or "Mechanical Stress" Or "vibration\*" Or "whole body vibration"

S2 ( (spine or spinal or vertebr\* or interverteb\* or disk\* or disc\*) n3 (degenerat\* or displace\* or injur\* or damage\* or herniat\*) ) OR (MH "Intervertebral Disk Displacement")

S3 embase

S4 (S1 and S2 and S3)

CINAHL EBSCO March 13 2017

1. (MH "Occupation (Human)") OR "occupation" OR (MH "Occupations and Professions")
2. (MH "Occupational Diseases") OR (MH "Injury, Occupational Disease, Poisoning")
3. (MH "Occupational Exposure")
4. (MH "Occupational Hazards")
5. (MH "Occupational Health")
6. "occupational load"
7. (MH "Lifting") OR "lifting" OR (MH "Lifting and Transfer Equipment") OR (MH "Weight Lifting")
8. (MH "Torque") OR "torque"
9. (MH "Weight-Bearing") OR "weigth bearing"
10. (MH "Stress, Mechanical") OR "mechanical stress"
11. (MH "Vibration") OR "vibration"
12. "whole body vibration"
13. (MH "Spine") OR "spine"
14. "spinal"
15. "spine degeneration"
16. (MH "Intervertebral Disk")
17. "disc degeneration"
18. "degenerative disk disease"
19. (MH "Lumbar Vertebrae") OR "lumbar vertebrae"
20. S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12
21. S13 OR S14 OR S15 OR S16 OR S18 OR S19
22. S20 AND S21

**Appendix 2: List of the 138 full text excluded studies with reasons for exclusion**

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| --- |
| **No outcome of interest** |
| * Riihimaki H, Wickstrom G, Hanninen K, Mattsson T, Waris P, Zitting A. Radiographically detectable lumbar degenerative changes as risk indicators of back pain. A cross-sectional epidemiologic study of concrete reinforcement workers and house painters. Scandinavian Journal of Work, Environment and Health. 1989;15(4):280-5. * Gibbons LE, Videman T, Battie MC. Isokinetic and psychophysical lifting strength, static back muscle endurance, and magnetic resonance imaging of the paraspinal muscles as predictors of low back pain in men. Scandinavian Journal of Rehabilitation Medicine. 1997;29(3):187-91. * Edeiken J, Karasick D. Use of radiography for screening employees for risk of low-back disability. Journal of Occupational Medicine. 1986;28(10):995-7. * Campbell C, Muncer SJ. The causes of low back pain: a network analysis. Social Science and Medicine. 2005;60(2):409-19. * Drerup B, Granitzka M, Assheuer J, Zerlett G. Assessment of disc injury in subjects exposed to long-term whole-body vibration. European Spine Journal. 1999;8(6):458-67. * Frymoyer JW, Rosen JC, Clements J, Pope MH. Psychologic factors in low-back-pain disability. Clinical Orthopaedics and Related Research. 1985(195):178-84. * Karahan A, Kav S, Abbasoglu A, Dogan N. Low back pain: prevalence and associated risk factors among hospital staff. Journal of Advanced Nursing. 2009;65(3):516-24. * Mazloum A, Nozad H, Kumashiro M. Occupational low back pain among workers in some small-sized factories in Ardabil, Iran. Industrial Health. 2006;44(1):135-9. * Mhaskar VA, Pai S. Does the occupational activity level affect the quality of life of patients treated with epidural steroid injections for lumbar disc herniations? Asian Spine Journal. 2012;6(2):131-5. * Omokhodion FO, Sanya AO. Risk factors for low back pain among office workers in Ibadan, Southwest Nigeria. Occupational Medicine 2003;53(4):287-9. * Palmer KT, Harris CE, Griffin MJ, Bennett J, Reading I, Sampson M, et al. Case-control study of low-back pain referred for magnetic resonance imaging, with special focus on whole-body vibration. Scandinavian journal of work, environment & health. 2008;34(5):364-73. * Seidler A, Bolm-Audorff U, Heiskel H, Henkel N, Roth-Kuver B, Kaiser U, et al. The role of cumulative physical work load in lumbar spine disease: risk factors for lumbar osteochondrosis and spondylosis associated with chronic complaints. Occupational and Environmental Medicine. 2001;58(11):735-46. * Seidler A, Bolm-Audorff U, Siol T, Henkel N, Fuchs C, Schug H, et al. Occupational risk factors for symptomatic lumbar disc herniation; a case-control study. Occupational & Environmental Medicine. 2003;60(11):821-30. * Videman T, Battie MC, Gibbons LE, Maravilha K, Manninen H, Kaprio J. Associations between back pain history and lumbar MRI findings. Spine 2003;28(6):582-8. * Dasinger LK, Krause N, Deegan LJ, Brand RJ, Rudolph L. Physical workplace factors and return to work after compensated low back injury: a disability phase-specific analysis. Journal of Occupational and Environmental Medicine. 2000;42(3):323-33. * Zhang YG, Sun Z, Zhang Z, Liu J, Guo X. Risk factors for lumbar intervertebral disc herniation in Chinese population: a case-control study. Spine. 2009;34(25):E918-22. * Alund M, Larsson SE, Lewin T. Work-related persistent neck impairment: A study on former steelworks grinders. Ergonomics. 1994;37(7):1253-60. * Schwarze S, Notbohm G, Hartung E, Dupuis H. Effects of whole-body vibrations on the lumbar spine. Arbeitsmedizin Sozialmedizin Umweltmedizin. 1998;33(10):429-42. * Jin J-y, Han S-l, Li K-p, Zhu J, Zhang J-l, Liao Y-h, et al. [Epidemiological investigation of back pain and spondyloarthritis in Shougang resident communities]. Chung-Hua Nei Ko Tsa Chih 2010;49(10):832-5. * Boos N, Semmer N, Elfering A, Schade V, Gal I, Zanetti M, et al. Natural history of individuals with asymptomatic disc abnormalities in magnetic resonance imaging: predictors of low back pain-related medical consultation and work incapacity. Spine. 2000;25(12):1484-92. * Luoma K, Riihimaki H, Luukkonen R, Raininko R, Viikari-Juntura E, Lamminen A. Low back pain in relation to lumbar disc degeneration. Spine. 2000;25(4):487-92. * Dupuis H, Zerlett G. Whole -body vibration and disorders of the spine. International Archives of Occupation and Enviromental Health. 1987;59(4):323-36. * Schenk P, Laubli T, Hodler J, Klipstein A. Symptomatology of recurrent low back pain in nursing and administrative professions. European Spine Journal. 2007;16(11):1789-98. * Virtanen IM, Karppinen J, Taimela S, Ott J, Barral S, Kaikkonen K, et al. Occupational and genetic risk factors associated with intervertebral disc disease. 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| **No non-exposure group** |
| * Leinonen V, Kankaanpaa M, Vanharanta H, Airaksinen O, Hanninen O. Back and neck extensor loading and back pain provocation in urban bus drivers with and without low back pain. Pathophysiology. 2005;12(4):249-55. * Seidler A, Euler U, Bolm-Audorff U, Ellegast R, Grifka J, Haerting J, et al. Physical workload and accelerated occurrence of lumbar spine diseases: risk and rate advancement periods in a German multicenter case-control study. Scandinavian journal of work, environment and health. 2011;37(1):30-6. * Bos E, Krol B, van der Star L, Groothoff J. Risk factors and musculoskeletal complaints in non-specialized nurses, IC nurses, operation room nurses, and X-ray technologists. International Archives of Occupational & Environmental Health. 2007;80(3):198-206. * Granhed H, Morelli B. Low back pain among retired wrestlers and heavyweight lifters. American Journal of Sports Medicine. 1988;16(5):530-3. * Tiemessen IJH, Hulshof CTJ, Frings-Dresen MHW. Low back pain in drivers exposed to whole body vibration: analysis of a dose-response pattern. Occupational & Environmental Medicine. 2008;65(10):667-75. * Macdonald EB, Porter R, Hibbert C, Hart J. The relationship between spinal canal diameter and back pain in coal miners. Ultrasonic measurement as a screening test? Journal of Occupational Medicine. 1984;26(1):23-8. * Aharony S, Milgrom C, Wolf T, Barzilay Y, Applbaum YH, Schindel Y, et al. Magnetic resonance imaging showed no signs of overuse or permanent injury to the lumbar sacral spine during a Special Forces training course. Spine Journal. 2008;8(4):578-83. * Landau DA, Chapnick L, Yoffe N, Azaria B, Goldstein L, Atar E. Cervical and lumbar MRI findings in aviators as a function of aircraft type. Aviation Space & Environmental Medicine. 2006;77(11):1158-61. * Baumann F, Beck A. Work-related spinal damage in jet pilots due to extreme acceleration. Zeitschrift fur Orthopadie und ihre Grenzgebiete. 1975;113(4):645-8. * Kristen H, Lukeschitsch G, Ramach W. Investigation of the lumbar vertebral column in light-transport workers. Arbeitsmedizin Sozialmedizin Praventivmedizin. 1981;16(9):226-9. * Sharma A, Lancaster S, Bagade S, Hildebolt C. Early pattern of degenerative changes in individual components of intervertebral discs in stressed and nonstressed segments of lumbar spine: an in vivo magnetic resonance imaging study. Spine. 2014;39(13):1084-90. |
| **Not evaluating whole body vibration** |
| * Videman T, Battie MC, Gibbons LE, Manninen H, Gill K, Fisher LD, et al. Lifetime exercise and disk degeneration: an MRI study of monozygotic twins. Medicine & Science in Sports & Exercise. 1997;29(10):1350-6. * Kelsey JL. An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. International journal of epidemiology. 1975;4(3):197-205. * Auerbach JD, Weidner ZD, Milby AH, Diab M, Lonner BS. Musculoskeletal disorders among spine surgeons: results of a survey of the scoliosis research society membership. Spine. 2011;36(26):E1715-21. * Bishop MD, Horn ME, Lott DJ, Arpan I, George SZ. Magnitude of spinal muscle damage is not statistically associated with exercise-induced low back pain intensity. Spine Journal. 2011;11(12):1135-42. * Boos N, Rieder R, Schade V, Spratt KF, Semmer N, Aebi M. 1995 Volvo Award in clinical sciences. 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An epidemiologic study of sports and weight lifting as possible risk factors for herniated lumbar and cervical discs. American Journal of Sports Medicine. 1993;21(6):854-60. * Pransky G, Foley G, Cifuentes M, Webster BS. Geographic variation in early MRI for acute work-related low back pain and associated factors. Spine. 2015;40(21):1712-8. * White JA, Wright V, Hudson AM. Relationships between habitual physical activity and osteoarthrosis in ageing women. Public Health (Nature). 1993;107(6):459-70. * Witwit WA, Kovac P, Sward A, Agnvall C, Todd C, Thoreson O, et al. Disc degeneration on MRI is more prevalent in young elite skiers compared to controls. Knee Surg Sports Traumatol Arthrosc. 2018;26(1):325-32. * Sward L, Hellstrom M, Jacobsson B, Peterson L. Back pain and radiologic changes in the thoraco-lumbar spine of athletes. Spine (Phila Pa 1976). 1990;15(2):124-9. * Tenforde AS, Carlson JL, Sainani KL, Chang AO, Kim JH, Golden NH, et al. 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| **Not a cohort or cross-sectional study** |
| * Bono CM. Current concepts review: low-back pain in athletes. Journal of Bone and Joint Surgery, American Volume. 2004;86A(2):382-96. * Franco JL. Modic changes: "Age, si quid agis"... Eur Spine J. 2006 Sep;15(9):1312-9. European Spine Journal. 2008;17(12):1766-8. * Rainville J, Kim RS, Katz JN. A review of 1985 Volvo Award winner in clinical science: Objective assessment of spine function following industrial injury: a prospective study with comparison group and 1-year follow-up. Spine. 2007;32(18):2031-4. * Williams FM, Sambrook PN. Neck and back pain and intervertebral disc degeneration: Role of occupational factors. Bailliere's Best Practice and Research Clinical Rheumatology. 2011;25(1):69-79. * Chaffin DB. Manual materials handling: the cause of over-exertion injury and illness in industry. Journal of Environmental Pathology & Toxicology. 1979;2(5):31-66. * Harley WJ. Lost time back injuries: their rrelationship to heavy work and preplacement back x-rays. Journal of occupational medicine. 1972;14(8):611-4. * Borenstein DG, Burton JR. Lumbar spine disease in the elderly. Journal of the American Geriatrics Society. 1993;41(2):167-75. * Williams FMK, Popham M, Livshits G, Sambrook PN, Spector TD, MacGregor AJ. A response to Videman et al., "Challenging the cumulative injury model: positive effects of greater body mass on disc degeneration". Spine Journal. 2010;10(6):571-2. * Videman T, Nurminen M, Troup JD. 1990 Volvo Award in clinical sciences. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation, and physical loading. Spine. 1990;15(8):728-40. * Arun R, Freeman BJ, Scammell BE, McNally DS, Cox E, Gowland P. 2009 ISSLS Prize Winner: What influence does sustained mechanical load have on diffusion in the human intervertebral disc?: an in vivo study using serial postcontrast magnetic resonance imaging. Spine. 2009;34(21):2324-37. * Belfi LM, Ortiz AO, Katz DS. Computed tomography evaluation of spondylolysis and spondylolisthesis in asymptomatic patients. Spine. 2006;31(24):E907-E10. * Farfan HF, Cossette JW, Robertson GH, Wells RV, Kraus H. The effects of torsion on the lumbar intervertebral joints: the role of torsion in the production of disc degeneration. Journal of bone and joint surgery, American volume. 1970;52(3):468-97. * Gunning JL, Callaghan JP, McGill SM. Spinal posture and prior loading history modulate compressive strength and type of failure in the spine: A biomechanical study using a porcine cervical spine model. Clinical Biomechanics. 2001;16(6):471-80. * Olsewski JM, Schendel MJ, Wallace LJ, Ogilvie JW, Gundry CR. Magnetic resonance imaging and biological changes in injured intervertebral discs under normal and increased mechanical demands. Spine. 1996;21(17):1945-51. * Bible JE, Choemprayong S, O'Neill K, Devin CJ, Spengler DM. Whole-body vibration. Is there a causal relationship to specific imaging findings of the spine? Spine 2012;37(21):E1348-E55. * Gooyers CE, McMillan RD, Howarth SJ, Callaghan JP. The impact of posture and prolonged cyclic compressive loading on vertebral joint mechanics. Spine. 2012;37(17):E1023-E9. * Stemper BD, Baisden J, Yogamandan N, Pintar FA, Tarima S, Xiang Q, et al. Lumbar spine injury tolerance during high-rate axial loading. Spine Journal. 2013;13:13S-4S. * Brinckmann P, Frobin W, Biggemann M, Hilweg D, Seidel S, Burton K, et al. Quantification of overload injuries to thoracolumbar vertebrae and discs in persons exposed to heavy physical exertions or vibration at the work-place. Clinical Biomechanics. 1994;9(SUPPL. 1):S1-S83. * Arora M, Paoloni JA, Kandwal P, Diwan AD. Are fast-bowlers prone to back injuries? Prevalence of lumbar spine injuries in fast-bowlers: review of MRI-based studies. Asian Journal of Sports Medicine. 2014;5(4):e24291. * Beck W. Intervertebral disc pathology of the cervical and lumbar spine, seen as a work-related disease caused by lifting and carrying heavy loads for many years. Krankengymnastik. 1998;50(5):838-42. |
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