Brief Report

Lower Back Problems and Occupational Risk Factors in a South African Steel Industry

Bernard J. van Vuuren, MA,[1,2]* Piet J. Becker, PhD,[3,4] Hendrik J. van Heerden, DPh,[1] Evert Zinzen, PhD,[5] and Romain Meeusen, PhD[2]

Background *The etiology of work-related back disorders is often population specific. The objective of this study was to identify and establish the association of occupational risk factors with the prevalence of low back (LB) problems in a semi-automated South African Steel industry.*
Methods *The design entailed an analytical cross-sectional epidemiological study among a group of 366 steel plant workers. Outcome of LB problems was defined using a guided questionnaire and a functional rating index. Exposure to occupational risk factors was determined using self-reported questionnaires.*
Results *Multivariate logistic regression analyses indicated significant adjusted odds ratios (OR) for twisting and bending (OR 2.81; CI 1.02–7.73); bulky manual handling (5.58; 1.16–26.71); load carriage (7.20; 1.60–32.37); prolonged sitting (2.33; 1.01–5.37); kneeling and squatting (4.62; 1.28–16.60); and working on slippery and uneven surfaces (3.63; 1.20–10.90).*
Conclusions *This study supports the current view of a multifactorial etiology in idiopathic LB problems, and emphasizes the importance of multiple intervention strategies in industrial settings.* Am. J. Ind. Med. 47:451–457, 2005. *© 2005 Wiley-Liss, Inc.*

KEY WORDS: back pain; risk factors; steel workers; occupational; industrial; ergonomics; South Africa

INTRODUCTION

Lower back (LB) problems are common in industrialized countries, with literature reporting various prevalence and incidence rates. International studies over the past three decades have reported point prevalence rates between 12% and 35% and lifetime prevalence rates ranging from 30% to 80% [Biering-Sorensen, 1982; Waddell, 1987; Frymoyer and Cats-Baril, 1991; Scovron et al., 1994; Maniadakis and Gray, 2000; Lee et al., 2001; Quittan, 2002; Zinzen, 2002], thus indicating a definite problem. The consequences of LB problems are often far reaching with sufferers experiencing levels of disability, reduced quality of life, as well as physical and psychological distress. This often leads to increased absence from work, lost productivity and work related

[1]Department of Biokinetics, Sport and Leisure Sciences, University of Pretoria, Pretoria, South Africa
[2]Department of Human Physiology & Sports Medicine, Faculty LK, Vrije Universiteit Brussel, Brussels, Belgium
[3]Biostatistics Unit, Medical Research Council of South Africa, Pretoria, South Africa
[4]Department of Clinical Epidemiology, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa
[5]Department of Movement Education and Sportstraining, Faculty LK, Vrije Universiteit Brussel, Brussels, Belgium
*Correspondence to: Bernard J. van Vuuren, Department of Biokinetics, Sport and Leisure Sciences, LC de Villiers Sport Centre, University of Pretoria, Pretoria 0002, South Africa. E-mail: bernard.vanvuuren@up.ac.za

Accepted 16 February 2005
DOI 10.1002/ajim.20164. Published online in Wiley InterScience (www.interscience.wiley.com)

© 2005 Wiley-Liss, Inc.

injuries, which in turn are associated with increased economic costs [Harkness et al., 2003].

Despite the large number of epidemiological studies in the past three decades, the etiology and risk factors of work-related back disorders are not well understood [Marras, 2001]. It is, however, commonly accepted today that back disorders are multifactorial in origin and may be associated with occupational, work-related psychosocial, and nonwork-related factors and characteristics [Bigos et al., 1992; NIOSH, 1997; Vlaeyen and Linton, 2000; Volinn et al., 2001; Vowles and Gross, 2003]. The presence of one risk factor does not negate the possibility that other risk factors also contribute to LB problems, but the focus of this specific study is restricted to occupational factors only. The most frequently reported occupational risk factors for LB problems from international studies are heavy physical work; frequent bending, twisting, lifting, pulling, and pushing; repetitive work; forceful movements; static postures like prolonged sitting, awkward postures and whole-body vibrations [Walsh et al., 1989; Punnett et al., 1991; Snook and Ciriello, 1991; Kjellberg et al., 1994; Hildebrandt, 1995; Toroptsova et al., 1995; Burdorf and Sorock, 1997; Hoozemans et al., 1998; Marras et al., 1998; Hoogendoorn et al., 1999; Kuiper et al., 1999; Lings and Leboeuf–Yde, 2000; Marras et al., 2003; Solomonow et al., 2003]. These risks are, however, occupation and population specific. Additional studies of worksite-based LB problems thus remain necessary to elucidate the associations between work tasks and LB problems onset [Kraus et al., 1997].

The identification of occupational risks for LB problems in the semi-automated South African industry remains virtually unexplored. One of the few published studies in this region only considered general musculoskeletal pain and ergonomic stressors in a group of 155 workers in the automotive manufacturing industry [Schierhout et al., 1993]. The present study, however, is part of a larger research project to assist the South African industry in more successful management of lower back problems, by better understanding the complex associations between occupational exposures, personal and psychosocial factors, and work-related lower back problems [Van Vuuren et al., 2003]. The objective of this specific study was to establish the association of occupational risk factors with the prevalence of LB problems in a South African Steel industry.

MATERIALS AND METHODS

Subjects and Design

The design entailed an analytical cross-sectional epidemiological study among a group of 366 steel plant workers, with a mean age of 31.76 ± 7.80, and mean work exposure of 6.73 ± 5.47 years, performing various related tasks, throughout an entire plant (Table I).

TABLE I. Deployment Areas of Subjects; South African Steel Workers

Plant area	Number of workers: n (%)
Raw materials and steel melting plant	55 (15%)
Hot mills	81 (22%)
Cold mills	33 (9%)
Plate processing	36 (10%)
Finishing lines	52 (14%)
Maintenance	94 (26%)
Various	15 (4%)
Overall	366 (100%)

Measures and Instruments

Case definition

The Functional Rating Index (FRI), comprising 10 items to assess the extent to which low back problems has affected daily activities, developed and validated by Feise and Menke [2001] was applied to determine case definition. A FRI of $\geq 30\%$ perceived disability was used in the analyses as a stringent definition and the mere presence of back problems at the time, was used as an inclusive definition to record cases of LB problems.

Occupational Risks

The Occupational Risk Factor Questionnaire (ORFQ) developed and validated via test–retest and inter-rater reliability statistics by Halpern et al. [2001] comprising 26 self-report items, was utilized to measure occupational exposure. Five categories of risk factors that may be associated with LB problems, viz. work organization, trunk posture, handling activities, body position, and environmental demands were probed. Accordingly, responses describing the duration of exposure to occupational risks in the work setting (items 6–22) as being "half the time" or more were classified as exposed cases. Similarly responses describing the frequency of lifting tasks (items 23–26) as being 11–30 or more times per hour, were classified as exposed cases.

Procedures

The relevant ethics committee approved the design and procedures, and the study was furthermore conducted with the informed consent of all parties and in accordance with the declaration of Helsinki. To ensure reliability and representation, anonymity was assured and the questionnaires were administrated during guided explanatory sessions of 5–10 workers per session. The FRI is known for its reliability, validity, and responsiveness [Feise and Menke, 2001]. This was confirmed in the South African industrial population, with high internal consistency (Cronbach alpha values) being recorded (CA 0.91) in a pilot study. Good internal consistency was recorded for the ORFQ with a Cronbach alpha value of 0.89. Similarly high test–retest reliability (frequency of differences <20%) for the FRI and ORFQ was recorded in the pilot study.

Statistical Analyses

For the assessment of risk factors, adjusted ORs followed from logistic regression analyses. Poor psychosocial characteristics and high biomechanical demands may covary. This covariation raises the possibility of confounding if both types of risk factors are not accounted for in risk models [Davis and Heaney, 2000]. This, however, was one of the strong points of this study where both characteristics were investigated in the same worker group, and all the observed potential risk factors were included in the logistic regression analyses to control for the confounding effects. In the statistical analyses, testing was done at the 0.05 level of significance. Where appropriate, and where the data was of a ratio nature, standard descriptive statistics (means and standard deviations) were employed. The statistical data analysis was performed using Stata Release 8, Stata Press, Stata Corporation, College Station, Texas. Copyright 1985–2003.

RESULTS

Summary statistics of the results of this study are shown in Tables II and III.

Using an inclusive definition (presence/absence of LB problems), lifetime and annual prevalence of LB problems were 63.9% and 55.7% respectively, with month and point prevalence being 41.3% and 35.8%, respectively. Using the FRI to measure perceived dysfunction and pain, 15.3% of the workers measured a 30% or higher disability (stringent outcome definition). Prevalence figures of different work tasks can be seen in Table II.

Multivariate analyses (logistic regression analyses), using the inclusive definition of LB problems indicated significant ORs for twisting and bending (2.81), carrying 5–15 kg objects (7.20), and sitting (2.33) (Table III). Using the more stringent classification for LB problems significant ORs were found for bulky manual handling (5.58), kneeling and squatting (4.62), and working on slippery and uneven surfaces (3.63) (Table III).

DISCUSSION

Prevalence

Comparing prevalence and incidence rates of LB problems in the literature may be imprudent because of the various definitions of LB problems. It is, however, interesting to note that the lifetime prevalence (63.9%) among the workers in this study was lower than that often quoted (80%) in literature [Waddell, 1987]. The average age of this population (32 years) is, however, young compared to other studies of lifetime prevalence of LB problems. Therefore, it is not surprising that the lifetime prevalence rates reported in this study are lower than those reported elsewhere. While 35.8% of the workers indicated to have some form of LB problems at the time of data capturing, only 15.3% of the workers seem to have more serious conditions, which in fact limits their daily activities. These findings are in accordance with point prevalence rates between 12% and 35% mentioned at the outset, yet stresses the importance of considering definitions of outcome in evaluating the prevalence of LB problems.

TABLE II. Prevalence of Lower Back Problems for Different Work Tasks in a South African Steel Industry

	Point prevalence (inclusive definition)		Point prevalence (stringent definition)	
Work task (n = 366)	**Prevalence (%)**	**CI 95%**	**Prevalence (%)**	**CI 95%**
Overhead crane operators (n = 41)	36.59	21–52	14.63	3–26
Cabin crane operators (n = 5)	80.00	24–136[a]	20.00	0–76[a]
Tapping station workers (n = 6)	33.33	0–88[a]	16.67	0–60[a]
Process controllers (n = 46)	34.78	20–49	17.39	6–29
Section controllers (n = 74)	31.08	20–42	20.27	11–30
Maintenance workers (n = 94)	37.23	27–47	12.77	6–20
Computer based workers (n = 14)	64.29	36–93[a]	21.43	0–46[a]
Managers (n = 25)	40.00	19–61	24.00	6–42
Roll builders (n = 24)	45.83	24–67	12.50	0–27
Support workers (n = 15)	26.67	1–52[a]	0.00	0–0
Apprentice workers (n = 22)	9.09	0–22	4.55	0–14

[a]Confidence intervals are broad, due to small sub sample numbers. This however is true to the nature of the specific plant.

TABLE III. Summary Statistics of Study Findings

Variables	Multivariate analyses adjusted ORs			
	OR inclusive definition	CI 95%	OR stringent (FRI) definition	CI 95%
45° trunk flexion	1.32	0.59–2.96	1.25	0.47–3.35
90° trunk flexion	0.67	0.22–2.09	0.48	0.14–1.62
Twisting (45°) and bending of trunk	2.81	1.02–7.73*	0.87	0.30–2.56
Bulky manual handling	0.33	0.74–1.51	5.58	1.16–26.7*
One hand manual handling	0.98	0.24–4.05	0.36	0.07–1.84
Unstable manual handling	3.48	0.60–20.19	0.24	0.02–2.35
Pushing and pulling	0.29	0.06–1.37	0.60	0.15–2.40
Carrying 5–15 kg objects	7.20	1.60–32.4*	2.23	0.53–9.31
Carrying objects >15 kg	0.34	0.05–2.40	0.42	0.07–2.54
Carrying objects >5 kg, >10 m	1.39	0.27–7.08	2.88	0.63–13.23
Sitting	2.33	1.01–5.37*	1.89	0.75–4.78
Kneeling and squatting	1.95	0.58–6.49	4.62	1.28–16.6*
Stair climbing	0.48	0.20–1.11	0.46	0.18–1.21
Using powered hand tools	0.31	0.09–1.10	0.27	0.07–1.10
Driving trucks, forklifts etc.	1.25	0.42–3.74	0.79	0.23–2.68
Working on slippery and uneven surfaces	1.25	0.38–4.12	3.63	1.20–10.9*
Working on elevated surfaces	1.29	0.21–7.80	0.42	0.05–3.25
Lifting <5 kg	1.76	0.34–9.04	0.71	0.17–3.01
Lifting 5–15 kg	0.70	0.09–5.67	5.54	0.78–39.46
Lifting >15 kg	0.61	0.05–7.43	1.17	0.11–12.44

*$P < 0.05$.

Trunk Posture

The combination of twisting and bending was the only trunk posture variable, which was significantly associated with LB problems (Table III). These findings are inconsistent with positive multivariate associations reported in literature between LB problems and flexion posture independent of twisting [Burdorf et al., 1991; Punnett et al., 1991; Hoogendoorn et al., 2000], but support numerous other epidemiologic studies which identified axial twisting of the torso as a significant risk factor for occupationally-related LB problems [Kelsey et al., 1984; Kahanovitz, 1991; Marras et al., 1993; NAS, 2001]. The torsion forces that develop with combined twisting and flexion are well known [NIOSH, 1997; McGill, 2002], and it is therefore advisable for this industry to monitor the occupational activities, such as cabin crane operating, tapping work, and maintenance work, which comprise bending, twisting and turning of the spine.

Handling Activities

A significant association (OR 5.58) was found between bulky manual handling and LB problems (Table III). This finding was notable, taking into consideration that most workers in this industry generally perform light work-related tasks due to of the semi-automated nature of the factory. Heavy manual work was the exception in this factory, only taking place sporadically. Such manual handling was further carried out mainly by section and process controllers who sit in a control room for long hours and may suddenly be called upon to perform some kind of manual handling. The high stringent LB problems prevalence figures in these two groups (Table II), together with the data observed for sitting (ORs of 2.33 and 1.89) sketch an interesting scenario, which may be attributed to loading memory of the spine [McGill, 2002]. Prolonged flexion (during sitting) causes posterior ligamentous creep [Adams and Hutton, 1988], together with a redistribution of the nucleus within the annulus [McKenzie, 1979]. McGill and Brown [1992] showed that in 2 min following 20 min of full flexion, only half of intervertebral joint stiffness was regained. Even after 30 min some residual joint laxity remains [McGill and Brown, 1992]. It could thus be possible that these workers perform bulky handling tasks with ‘‘unstable’’ backs, due to the prolonged sitting posture. Another possible explanation for bulky handling being a significant risk factor in our study is that the sporadic exposure, often because of machine breakdown, does not lead to work hardening and workers have a lower load capacity.

Load Carriage

Another risk factor that was highly associated with LB problems was load carriage with a high OR of 7.20 (Table III). This is consistent with the National Academy of Sciences (NAS) [2001] which found attributable risk to be between 11% and 66% for lifting and carrying of loads, while various others also found load carriage to be associated with LB problems [Reynolds et al., 1990; Erkintalo et al., 1995; Grimmer and Williams, 2000]. In a solitary South African study dealing with musculoskeletal pain and workplace stressors [Schierhout et al., 1993], the total lifting score was found to be significantly associated with LB problems. Considering the weight range (5–15 kg), which was associated with risk in this study, a specific sub cohort of overhead crane-operators are worth mentioning. Their primary task is to operate the overhead cranes with an operating device for working shifts of 8 hr. Such operators, which are very common in the factory, carry devices of 5 kg for most of the day. Depending on the working area, these workers will walk for long distances, while operating the overhead cranes. Another group of workers frequently exposed to the carriage of lightweight tools in this factory are those carrying out daily maintenance. These maintenance workers are expected to carry their tools with them throughout the factory for the greater part of the workday.

Body Position

Significant associations with LB problems were found for sitting, kneeling and squatting (Table III). Literature findings on these variables are inconsistent with some researchers demonstrating associations [Walsh et al., 1989; Holmstrom et al., 1992; Masset and Malchaire, 1994], while others don't [Svensson and Andersson, 1989; Holmstrom et al., 1992]. In a recent study by Harkness et al. [2003] they found no associations between sitting and LB problems, while they found kneeling (OR 2.1) and squatting (OR 1.8) for 15 min or longer to be a predictor factor for new-onset LB problems in 1,186 new employees. In a typical Steel plant today one finds various control rooms where workers sit for prolonged periods of time. Even the ''manual worker,'' has longer periods of sitting because of the semi-automated nature of most industrial plants. This was also true of our study site, where machines performed a large part of the work tasks. Some areas in a steel factory also require long periods of kneeling and squatting for workers to perform their daily activities. This is especially true for maintenance workers, which are often exposed to long periods of kneeling and poor spinal posture (prolonged flexion of the lumbar spine), which in turn could lead to ligamentous creep and spinal instability.

Environmental Demands

Working on slippery and uneven surfaces was associated (OR 3.63), with LB problems in this study. Although this specific factory is very clean, areas exist where slippery surfaces may occur. Literature is limited on this risk factor, but in most ergonomic guides one will find recommendations on tidy and clean work areas, to prevent slipping, especially during manual handling tasks, which may lead to injury to the spine [Van der Burg et al., 2000].

A strong point of this specific study was the way in which occupational exposure was measured. One finds in studies with high numbers, that physical factors are more than often measured at the group (e.g., job or task) level and often by methods with limited precision or accuracy. In this study self-reported occupational risk factors were assessed on an individual basis, with a valid and reliable tool (ORFQ).

A noteworthy limitation is the cross-sectional character of this study, which does not permit causal inferences regarding the associations found. A cross-sectional study, which is often utilized with first forays into new areas of investigation [Grimes and Schulz, 2002] was thus adopoted due to the possibility of poor follow-up which is a real threat in these industrial settings. Furthermore, it was the first time that these instruments would be applied in a South African industrial situation. It is however recommended that prospective studies will follow in the South African industrial population so that the temporal relationship between exposure and outcome can be established.

In conclusion, the different occupational risk variables in our study, which indicated significant associations with LB problems were twisting and bending of the trunk, bulky manual handling, light load carriage, sitting, kneeling and squatting, and working on slippery and uneven surfaces. Our results illustrate the specificity of every industrial setting, and confirm the necessity of regional and industry specific studies to plan preventative measures to decrease LB problems in industry. This study further confirms the current view of a multifactorial etiological approach to idiopathic LB problems in particular, and emphasizes the importance of multiple intervention strategies.

ACKNOWLEDGMENTS

The authors would like to thank the management, in particular Deon van Vuuren, and the workforce of the specific steel plant under study for their cooperation.

REFERENCES

Adams MA, Hutton WC. 1988. Mechanics of the intervertebral disc. In: Ghosh P, editor. The biology of the intervertebral disc. Boca Raton, FL: CRC Press.

Biering-Sorensen F. 1982. Low back trouble in a general population of 30- 40-, 50-year old males and females: Study design, representativeness and basic results. Dan Med Bull 29:289–299.

Bigos SJ, Battie MC, Spengler DM, Fisher LD, Fordyce WE, Hansson TH, Nachemson AL, Zeh J. 1992. A longitudinal, prospective study of industrial back injury reporting. Clin Orthop 279:21–34.

Burdorf A, Sorock G. 1997. Positive and negative evidence of risk factors for back disorders. Scand J Work Environ Health 23(4):243–256.

Burdorf A, Govaert G, Elders L. 1991. Postural load and back pain of workers in the manufacturing of prefabricated concrete elements. Ergonomics 34(7):909–918.

Davis KG, Heaney CA. 2000. The relationship between psychosocial work characteristics and low back pain: Underlying methodological issues. Clin Biomech 15:389–406.

Erkintalo M, Salminen J, Alanen A, Paajanen H, Kormano M. 1995. Development of degenerative changes in the lumbar intervertebral disk: Results of a prospective MR imaging study in adolescents with and without low-back pain. Radiology 196:529–533.

Feise RJ, Menke JM. 2001. Functional rating index. A new valid and reliable instrument to measure the magnitude of clinical change in spinal conditions. Spine 26(1):78–87.

Frymoyer JW, Cats-Baril WL. 1991. An overview of the incidences and costs of low back pain. Orthoped Clin N Am 22:263–271.

Grimes DA, Schulz KF. 2002. An overview of clinical research: The lay of the land. Lancet 359:57–61.

Grimmer K, Williams M. 2000. Gender-age environmental associates of adolescent low back pain. Appl Ergon 31(4):343–360.

Halpern M, Hiebert R, Nordin M, Goldheyden D, Crane M. 2001. The test–retest reliability of a new occupational risk factor questionnaire for outcome studies. Appl Ergon 32(1):39–46.

Harkness EF, Macfarlane GJ, Nahit ES, Silman AJ, McBeth J. 2003. Risk factors for new-onset low back pain amongst cohorts of newly employed workers. Rheumatology 42:959–968.

Hildebrandt VH. 1995. Back pain in the working population: Prevalence rates in Dutch trades and professions. Ergonomics 38(6):1283–1298.

Holmström EB, Lindell J, Moritz U. 1992. Low back and neck/shoulder pain in construction workers: occupational work-load and psychosocial risk factors. Spine 17(6):663–671.

Hoogendoorn WE, van Poppel MNM, Koes BW, Bouter LM. 1999. Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health 25(5):387–403.

Hoogendoorn WE, Bongers PM, de Vet HCW, Douwes M, Koes BW, Miedema MC, Ariëns GAM, Bouter LM. 2000. Flexion and rotation of the trunk and lifting at work are risk factors for low back pain. Results of a prospective cohort study. Spine 25(23):3078–3092.

Hoozemans MJM, Van der Beek AJ, Frings-Dresen MHW, Van Dijk FJH, Van der Woude LHV. 1998. Pushing and pulling in relation to musculoskeletal disorders: A review of risk factors. Ergonomics XX(41):757–781.

Kahanovitz N. 1991. Diagnosis and treatment of low back pain. New York: Raven Press. p 133–136.

Kelsey JL, Githens PB, White AA, Holford TR, Walter SD, O'Connor T, Ostfeld AM, Weil U, Southwick WO, Calogero JA. 1984. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. J Orthop Res 2(1):61–66.

Kjellberg A, Eikström BO, Landström U. 1994. Injuries and other adverse effects of occupational exposure to whole- body vibration. A review for criteria documentation. Arb Hälsa 41.

Kraus JF, Gardner L, Collins J, Sorock G, Volinn E. 1997. Design factors in epidemiological cohort studies of work-related low back injury or pain. Am J Ind Med 32:153–163.

Kuiper JI, Burdorf A, Verbeek JHAM, Frings-Dresen MHW, Van der Beek AJ, Viikari-Juntura E. 1999. Epidemiological evidence on manual materials handling as a risk factor for back disorders: A systematic review. Int J Ind Ergon 24:389–404.

Lee P, Helewa A, Goldsmith CH, Smythe HA, Stitt LW. 2001. Low back pain: Prevalence and risk factors in an industrial setting. J Rheumatol 28(2):346–351.

Lings S, Leboeuf–Yde C. 2000. Whole-body vibration and low back pain: A systematic, critical review of the epidemiological literature 1992–1999. Int Arch Occup Environ Health 73:290–297.

Maniadakis N, Gray A. 2000. The economic burden of back pain in the UK. Pain 84:95–103.

Marras WS. 2001. Spine biomechanics, government regulation, and prevention of occupational low back pain. Editorial. Spine J 1(3):163–165.

Marras W, Lavender S, Leurgans S, Rajulu SL, Allread WG, Fathallah FA, Ferguson SA. 1993. The role of three-dimensional trunk motion in occupationally-related low back disorders: The effects of work-place factors, trunk position, and trunk motion characteristics on risk of injury. Spine 18(5):617–628.

Marras WS, Davis KG, Granata KP. 1998. Trunk muscle activities during asymmetric twisting motions. J Electromyogr Kinesiol 8(4): 247–256.

Marras WS, Davis KG, Jorgensen M. 2003. Gender influences on spine loads during complex lifting. Spine J 3(2):93–99.

Masset D, Malchaire J. 1994. Low back pain: Epidemiologic aspects and workrelated factors in the steel industry. Spine 19(2):143–146.

McGill S. 2002. Low back disorders. Evidence-based prevention and rehabilitation. Human Kinetics, Champaign. See pages 113–124; 161–184.

McGill SM, Brown S. 1992. Creep response of the lumbar spine to prolonged lumbar flexion. Clin Biomech 7:43.

McKenzie RA. 1979. Prophylaxis in recurrent low back pain. N Z Med J 89:22.

National Research Council and the Institute of Medicine. 2001. Musculoskeletal disorders and the workplace: low back and upper extremities. Panel on musculoskeletal disorders in the workplace. Commission on behavioral and social sciences and education. Washington, DC: National Academy Press, p 83–183.

NIOSH. 1997. Executive summary/Chapter 6: Low back and musculoskeletal disorders: Evidence for work-relatedness. In: Bernard BP, editor. Musculoskeletal disorders (MSDs) and workplace factors/ TOC. Cincinnati, OH: National Institute for Occupational Safety and Health.

Punnett L, Fine LJ, Keyserling WM, Herrin GD, Chaffin DB. 1991. Back disorders and nonneutral trunk postures of automobile assembly workers. Scand J Work Environ Health 17(5):337–346.

Quittan M. 2002. Management of back pain. Disabil Rehabil 24(8): 423–434.

Reynolds KL, Kaszuba J, Mello RP, Patton JF. 1990. Prolonged treadmill load carriage: acute injuries and changes in foot anthropometry. Technical Report T1/91. Natick MA: US Army Research Institute of Environmental Medicine.

Schierhout GH, Myers JE, Bridger RS. 1993. Musculoskeletal pain and workplace ergonomic stressors in manufacturing industry in South Africa. Int J Ind Ergon 12:3–11.

Scovron ML, Szalski M, Nordin M, Melot C, Cucier D. 1994. Socioeconomic factors and back pain. Spine 19:129–137.

Snook SH, Ciriello VM. 1991. The design of manual handling tasks: Revised tables of maximum acceptable weights and forces. Ergonmics 34(9):1197–1213.

Solomonow M, Baratta RV, Banks A, Freudenberger C, Zhou BH. 2003. Flexion–relaxation response to static lumbar flexion in males and females. Clin Biomech 18(4):273–279.

Svensson H, Andersson GBJ. 1989. The relationship of low-back pain, work history and work environment, and stress: A retrospective cross-sectional study of 38- to 64-year old women. Spine 14(5):517–522.

Toroptsova NV, Benevolenskaya CI, Karyakin AN, Sergeev IL, Erdesz S. 1995. ‘‘Cross-sectional ’’ study of lower back pain among workers at an industrial enterprise in Russia. Spine 20(3):328–332.

Van der Burg JCE, van Dieën JH, Toussaint HM. 2000. Lifting an unexpectedly heavy object: The effects on low-back loading and balance loss. Clin Biomech 15(7):469–477.

Van Vuuren B, Van Heerden J, Becker P, Zinzen E, Meeusen R. 2003. Lower back problems among workers at two industrial sites in South Africa. Med Sci Sports Exerc 35:S334.

Vlaeyen JWS, Linton SJ. 2000. Fear-avoidance and its consequences in chronic musculoskeletal pain: A state of the art. Pain 85:317–332.

Volinn E, Spratt KF, Magnusson M, Pope MH. 2001. The Boeing Prospective Study and beyond. Spine 26(14):1613–1622.

Vowles KE, Gross RT. 2003. Work-related beliefs about injury and physical capability for work in individuals with chronic pain. Pain 101(3):291–298.

Waddell G. 1987. A new clinical model for the treatment of low back pain. Spine 1:632–644.

Walsh K, Varnes N, Osmond C, Styles R, Coggin D. 1989. Occupational causes of low back pain. Scand J Work Environ Health 15(1):54–59.

Zinzen E. 2002. Epidemiology: Musculoskeletal problems in Belgium nurses. In: Reily T, editor. Musculoskeletal disorders in health-related occupations. Ohmsha: IOS Press. p 41–61.