SPINE Volume 18, Number 5, pp 595–602

An Epidemiologic Study of Non-Occupational Lifting as a Risk Factor for Herniated Lumbar Intervertebral Disc

Diane J. Mundt, PhD,* Jennifer L. Kelsey, PhD,† Anne L. Golden, PhD,‡ Harris Pastides, PhD,§ Anne T. Berg, PhD,¶ Joseph Sklar, MD,|| Timothy Hosea, MD,** Manohar M. Panjabi, PhD,†† and the Northeast Collaborative Group on Low Back Pain‡‡

An epidemiologic case-control study of herniated lumbar intervertebral disc was conducted in Springfield, Massachusetts, New Brunswick, New Jersey, and New York, New York, to evaluate the role of several possible risk factors in the etiology of this disorder. Patients with signs and symptoms of herniated lumbar disc (N = 287) were matched to control subjects without back pain by age, sex, source of care, and geographic area. Of the total case-subject group, 177 were confirmed by surgery, computed tomographic scan, myelogram, or magnetic resonance imaging. This article focuses on non-occupational lifting, an activity not previously reported on. Frequent lifting of objects or children weighing 25 or more pounds with knees straight and back bent was associated with increased risk of herniated lumbar disc. This association was particularly strong among confirmed case subjects (relative risk = 3.95). Positive associations among confirmed case subjects were also seen for frequent lifting with arms extended (relative risk = 1.87) and twisting while lifting (relative risk = 1.90). No associations were found for frequent stretching or carrying. If confirmed in other investigations, these data suggest that instruction in lifting techniques should be extended into the home. [Key words: herniated lumbar disc, epidemiology, non-occupational lifting]

From the *National Academy of Science, Institute of Medicine, Washington, DC, the †Department of Health Research and Policy, Stanford University School of Medicine, Stanford, California, the ‡Department of Community Medicine, Mt. Sinai School of Medicine, New York, New York, the §Department of Biostatistics and Epidemiology, University of Massachusetts School of Public Health, Amherst, Massachusetts, the Department of Pediatrics, Yale University, New Haven, Connecticut, ||New England Orthopedic Surgeons, Inc., Springfield, Massachusetts, the **Division of Orthopedic Surgery, UMDNJ-Robert Wood Johnson Medical School, New Brunswick, New Jersey, and the†† Department of Orthopedics and Rehabilitation, Yale University, New Haven, Connecticut.
‡‡The Northeast Collaborative Group on Low Back Pain is as follows: Doctors David Andrews, Robert Bye, Stephen Cook, Michael Coyle, Jr., William Cunningham, Demosthenes Dasco, John DeWeese, Harold Dick, Aiden Doyle, Richard Fingeroth, S. Ashby Grantham, Michael Handler, Neil Kahanovitz, Sumner Karas, Ira Kasoff, J. Robert Kirkwood, Joseph Leddy, Marc Linson, Jerry Lubliner, Morton Lynn, Marc Malberg, Christopher Michelson, W. Jost Michelson, Sabir Moghul, Arthur Pava, Michael Pirone, Mark Pohlman, Donald Polakoff, Kalmon Post, Andrea Resnick, Bernard Rineberg, Steven Schonfeld, Michael Silverstein, Sherman Stein, Alfred Tria, Jr., Leonard Wagner, Steven Wenner, and Joseph Zawadsky
The study was conducted at Columbia University, New York, NY and the University of Massachusetts, Amherst, MA.
Accepted October 1, 1992.

Low back pain is responsible for considerable activity limitation and time lost from work in otherwise healthy young adults. Herniated lumbar disc is among the more disabling causes of such pain. Increased risk of herniated lumbar disc has been associated with a number of risk factors,[25,26,28–30,32–35] including occupational lifting,[32] especially if the lifting is done while twisting the body,[32] and driving motor vehicles,[30,34] particularly older cars and cars produced by American manufacturers as compared to Scandinavian and Japanese manufacturers.[30] However, non-occupational lifting has not been evaluated in detail. This article therefore presents findings on the role of non-occupational lifting of inanimate objects and of children as risk factors for herniated lumbar disc. This was one component of an epidemiologic case-control study of herniated disc that covered a wide array of potential risk factors.

Methods

This case-control study of herniated lumbar disc was conducted at Columbia University in New York, and the University of Massachusetts in Amherst. Persons with herniated disc of recent onset aged 20–64 years were ascertained from December 1986 through November 1988 from 38 orthopaedic surgeons and neurosurgeons in private practice in Springfield, Massachusetts and New Brunswick, New Jersey, a physician at the Hospital for Joint Diseases in New York City, as well as from participating hospital emergency rooms in Springfield, Massachusetts (Mercy Hospital and Baystate Medical Center) and New Brunswick, New Jersey (St. Peter's Medical Center and Robert Wood Johnson University Hospital). Potential case subjects were identified through billing records for radiology to the lumbosacral spine (myelogram, computerized tomography scan, magnetic resonance imaging), as well as directly from lists of patients seen in several of the physicians' offices. A sample of patients seen in hospital emergency rooms with lumbosacral spine radiographic studies were also identified as potential case subjects; their radiographs were primarily plain roentgenographs.

Because a number of conditions besides herniated disc would result in referral for radiographic studies of the lumbosacral spine, those initially identified as potential case subjects were screened by means of record review and a brief questionnaire. Also, because this study was designed to include new cases of herniated disc, screening was used to exclude those patients who had symptoms of a chronic nature, that is, for more than one year before the date of the office visit or radiographic procedure (called the "accession date" here). The study was limited to new patients to ascertain circumstances and behaviors before herniated disc occurred. Inclusion of chronic patients or those with previous episodes of back and neck pain might have obscured associations of interest between potential risk factors and herniated disc, because these people are more likely to have modified behaviors in response to their pain.

Once a potential case subject was identified, reviews of radiology reports and medical records were used as a first step in excluding cases meeting any of the exclusion criteria to be listed below. Patients not initially excluded were contacted either directly at the physician's office or by letter. The eligibility of those who agreed to participate in the study was determined using a short structured screening questionnaire. This instrument asked about the patient's age, the date of onset of current symptoms, previous occurrence of the health problem, history of surgery for herniated disc, history of chronic back, leg, neck, or arm pain symptoms and extent of pain and/or numbness and tingling symptoms for current health problem. If a potential study participant was excluded during this screening, no further contact was made. All subjects potentially eligible after review of radiology reports, review of medical records and screening were invited to complete a comprehensive in-person interview.

Potential case subjects were excluded for the following reasons: 1) age at accession outside the 20–64 year range; 2) no pain, numbness or tingling in the hip, buttock, leg, or foot; 3) continuous pain, numbness, tingling in the low back, neck, legs, or arms for more than one year before accession; 4) previous surgery for herniated lumbar or cervical disc (more than one year before accession for current problem); 5) signs, symptoms, and radiographic results attributable to other conditions of the back or neck (e.g., tumors, osteoarthrosis, spondylolysis, spinal fracture, congenital abnormalities); 6) activity limitation occurring more than one year before accession from pain in the low back, legs, neck, or arms that lasted at least four weeks and was associated with a reduction in usual activities; an exception to this criterion was made when the pain had occurred in an extremity only, more than five years before onset of current symptoms, and lasted no more than 13 weeks (e.g., fractured arm or leg); 7) inability to speak English; 8) residence in areas identified by police as unsafe for interviewers; 9) residence outside certain geographically defined bounds for Massachusetts case subjects.

A total of 3,961 potential case subjects was identified. Of this total, 2,942 (74%) were excluded, 448 remained potentially eligible after screening and 571 were of unknown eligibility*. Of the 448 persons eligible for inclusion as case subjects, 355 (79%) were interviewed; of those persons interviewed, there were 297 cases of herniated lumbar disc. The other interviewed persons had cervical disc herniations, which are not included in this article.

Potential control subjects were other patients seen by the same participating orthopaedic surgeons or in the emergency room; they were identified from the same billing lists and patient lists as the case subjects but had conditions unrelated to the back or neck. Neurosurgical controls were not used, because most of those selected would have been excluded because of the severity or chronic nature of the illness; also, diseases associated with many neurologic impairments (e.g., of speech) would preclude an interview. Control subjects were individually matched by sex, decade of age, geographic location, and source of medical care (private practice or hospital emergency room) to 287 of the 297 (97%) cases. Exclusion criteria for potential control subjects were similar to those for cases, except exclusion criterion 2 (above) was changed to pain, numbness or tingling in the back or neck only; exclusion criterion 3 applied to the control subject's current health problem and exclusion criterion 5 was not applicable. All potential control subjects were administered the same screening questionnaire as the cases to provide information concerning eligibility; those who were not excluded were invited to participate in the in-person interview. Control subjects represented a number of diagnostic groups, including fractures (26%), sprains (19%), tendonitis/synovitis (12%), knee injuries (11%), other upper extremity diagnoses (9%), bruises and cuts (8%), other lower extremity diagnoses (5%), "pain" (5%), dislocations (4%), and other diagnoses (1%).

A total of 1941 potential control subjects was identified. Of the total, 878 (45%) were excluded, 472 were potentially eligible and 591 were of unknown eligibility. Of the 472 eligible control subjects, 359 (76%) were interviewed.

Cases included in this study were classified as confirmed or unconfirmed. Confirmed cases were those with a herniation, prolapse, rupture, protrusion, extrusion, extradural defect, or free fragment† noted on the surgical report, myelogram, computed tomographic scan, or magnetic resonance image; vertebral level of herniation was also noted from these sources. Unconfirmed cases included those classified as probable or possible on the basis of signs and symptoms consistent with herniated disc; level of lesion was not considered for these cases. A case was classified as "probable" if the patient had pain, numbness, or tingling radiating to the hip, buttock, thigh, and below the knee in a pattern consistent with nerve root impingement by the disc, with worsening of the pain, numbness or tingling with coughing, stretching the leg, or straining while moving the bowels. A case was classified as "possible" if one of the following three conditions was present in the patient: 1) pain, numbness or tingling radiating down the leg as described above, with no worsening with cough, stretch or strain; or 2) pain, numbness or tingling to the thigh *and* worsening with cough, stretch or strain *or* positive straight leg raising indicated in the medical record; or 3) pain, numbness or

*Those of unknown eligibility included potential case and control subjects for whom initial contact letters were returned by the post office; those who were unable to be located or had moved; those for whom a surrogate (e.g., spouse, physician) refused contact with the patient; those who refused before screening; or those for whom no phone number was available after checking all possible sources.

†Subsequent reference in the text to the term "herniation" will include all types of pathology listed here.

tingling in the lower leg only *and* worsening with cough, stretch or strain *or* positive straight leg raising. Straight leg raising information was not consistently present in medical records, and therefore was used only when available.

All case and control subjects believed to be eligible for inclusion were interviewed in person using the same structured questionnaire. In a few instances, potential patients and control subjects were excluded after this interview if the responses to the questionnaire indicated that they did not meet the inclusion criteria. All decisions regarding classification and inclusion were without knowledge of the subject's exposure to potential risk factors.

The questionnaire included items related to symptoms of the current health problem, occupational activities, use of motor vehicles, use of equipment that causes whole body and arm vibration, riding in planes, trains, buses, subways and motorcycles, off the job lifting (25+ lb inanimate objects, 10–24 lb children, 25+ lb children), carrying, stretching, bending, shovelling, pregnancy history, smoking history, participation in sports, and use of free weights and weight lifting equipment. Questions pertaining to lifting inanimate objects weighing less than 25 lb were not asked. For a response regarding lifting off the job to be considered positive, a minimum average frequency of lifting at least once a week for six months in the two years before the health problem began was required. Similarly, for a response regarding sports and weight lifting to be considered positive, a minimum level of participation of at least 10 times in the two years before the health problem began was required. The assessment of risk exposure was limited to the two years before the health problem began, as this period before injury was likely to represent "usual" patterns of activity for both case and control subjects, and could be more reliably answered than questions concerning physical activity earlier in life. Lifetime history of occupational lifting, bending, and twisting was also obtained in the interview. The referent group for each comparison consisted of those who did not perform the activity of interest. Several questions were accompanied by illustrations of the various options, such as diagrams of possible positions in which an object might be lifted from floor level. If more than one way of lifting was mentioned, subjects were asked to respond with the method used most frequently.

The relative risk (estimated by the odds ratio) was used as a measure of the magnitude of association between possible risk factors and herniated disc. The relative risk is the likelihood of developing the disease among those exposed, relative to those not exposed. For example, a relative risk of 2.0 indicates the disease is twice as likely among those exposed to the risk factor as compared to those not exposed. Conditional logistic regression analysis[18] was used to obtain adjusted estimates of the relative risk taking into account the effects of other variables of interest. The relative risk estimates presented are all adjusted for race, education, and number of cigarettes currently smoked. Adjusting for other variables in the model, such as occupational lifting, twisting while lifting, weight lifting or participation in sports, did not substantially affect risk estimates between the risk factors of interest and herniated disc; therefore, it was unnecessary to further control for these variables in the analysis. A 95% confidence interval around the relative risk gives an indication of the degree of precision of the relative risk. Results did not differ when examined separately for each study site; therefore, data from both sites were combined. Case subjects (n = 10) not matched to control subjects were excluded from analyses.

■ Results

Characteristics of the 287 cases, by confirmation status, are shown in Table 1. Fifty-nine percent of all cases were men; more than one third of all cases were in their 30s, with approximately 25% each in their 20s and 40s. The distribution of level of lumbar herniation and mean age by level of herniation are shown in Table 2. Herniations were most frequent at the L5–S1 level, and the mean age decreased with lower levels of herniation.

Case and control subjects were predominantly white, but more case subjects were nonwhite than matched control subjects. Also, control subjects had completed more years of education than had case subjects. Therefore, race and education were controlled for in all subsequent analyses. The number of cigarettes smoked in the year before the health problem began was associated with herniated lumbar disc. For each additional 10 cigarettes smoked per day on average, adjusted for race and education, the relative risk estimate was 1.38 (95% CI = 1.17–1.64). Subsequent analyses were also adjusted for the current amount smoked.

When all case subjects were considered, overall lifting of 25 lb or more off the job was not associated with herniated disc, but certain types of lifting were detrimental (Table 3). Specifically, lifting objects from

Table 1. Number and Percentage of Cases (n = 287) of Lumbar Disc Herniation by Confirmation Status and Age, Sex, and Source of Care

Variable	Confirmed* N (%)	Unconfirmed† N (%)
Sex		
Male	112 (63)	57 (52)
Female	65 (37)	53 (48)
Age		
20–29 yr	50 (28)	26 (24)
30–39 yr	65 (37)	38 (34)
40–49 yr	42 (24)	26 (24)
50–59 yr	12 (7)	16 (14)
60–64 yr	8 (4)	4 (4)
Source		
Private practice	172 (97)	81 (74)
Emergency room	5 (3)	29 (26)

* Confirmed cases (n = 177) were those with a herniation, rupture, protrusion, extrusion, extradural defect, or free fragment noted on the surgical, myelogram, CT scan, or MRI report.
† Unconfirmed cases (n = 110) included those classified as probable or possible on the basis of signs and symptoms consistent with herniated disc.

Table 2. Distribution of Confirmed Cases by Level of Herniation and Mean Age by Level of Herniation (n = 187)

Level	N (%)	Mean Age (yr)
L3–4	10 (6)	41
L4–5	52 (29)	38
L5–S1	88 (48)	35
L3–4 and L4–5	10 (6)	36
L4–5 and L5–S1	19 (10)	37
L3–4, L4–L5 and L5–S1	4 (2)	39

the floor with knees straight and back bent was associated a greater than twofold increased risk for herniated disc, whereas lifting with knees bent and back straight was negatively associated. Starting and ending the lift at waist level was also associated with herniated lumbar disc (relative risk [RR] = 2.03; 95% CI = 1.01–4.05). Only slightly increased risk for herniated disc was shown among those who started the lift with the arms extended or who twisted while lifting. No differences were found between groups with respect to frequency of lifting.

When the analysis was restricted to confirmed case subjects, (Table 3), the associations were stronger than for all case subjects combined. The adjusted relative risk estimate for lifting objects from floor level with knees straight and back bent was nearly twice as great among confirmed case subjects (RR = 3.95) as for all case subjects (RR = 2.25). Lifting objects from floor level and placing at floor level, lifting from waist level and placing at waist level, and to a lesser extent starting or ending the lift with arms extended, and twisting while lifting at least half the time were associated with herniation among confirmed case subjects. The wider confidence intervals reflect the smaller sample size for comparisons involving confirmed case subjects.

Lifting children was also evaluated (Table 4). Lifting children 10–24 lb was not associated with herniated lumbar disc unless the lifting was from the floor with knees straight and back bent. The risk associated with lifting children weighing 25 lb or more was elevated for lifting with the knees straight and back bent (RR = 1.95). Among confirmed case subjects, the associations for lifting children weighing 25 lb or more were generally similar to those presented for all case subjects combined.

Although not shown here, repeated stretching and carrying off the job were not associated with herniated lumbar disc. Repeated bending while doing off the job activities at least two days a week was weakly associated with lumbar herniation (RR = 1.39; 95% CI = 0.88–2.19 among all case subjects). Shovelling was negatively associated with herniated disc among all case subjects for shovelling 5–15 times in the two years before the health problem began (RR = 0.83,

Table 3. Estimated Relative Risk (RR) and 95% Confidence Intervals (95% CI) for Association Between Lifting 25 or More Pounds off the Job in the Two Years Before Health Problem Began and Herniated Lumbar Disc for All Cases Combined (n = 287) and Among Confirmed Cases Only (n = 177)*

		All Cases		Confirmed Only	
Variable	Variable Category†	RR	95% CI	RR	95% CF
Lifted at least once/wk for 6 mo	Yes	1.09	0.75–1.60	1.55	0.95–2.52
How lifted from floor	Knees bent, back straight	0.58	0.36–0.92	0.71	0.38–1.31
	Knees bent, back bent	1.16	0.59–2.30	2.02	0.83–4.90
	Knees straight, back bent	2.25	1.08–4.70	3.95	1.56–9.97
Level started lift	Floor/knee	0.99	0.65–1.50	1.45	0.85–2.48
	Waist or higher	1.42	0.80–2.54	1.79	0.85–3.77
Level ended lift	Floor/knee	1.03	0.61–1.72	1.62	0.84–3.12
	Waist or higher	1.17	0.76–1.78	1.59	0.92–2.73
Level lift started and ended	Floor to floor	1.13	0.64–1.99	1.84	0.89–3.79
	Floor to waist	0.94	0.59–1.52	1.31	0.71–2.40
	Waist to floor	0.75	0.28–2.01	0.86	0.22–3.45
	Waist to waist	2.03	1.01–4.05	2.53	1.07–6.01
Arms extended when lift started	Less than ½ the time	0.97	0.61–1.54	1.39	0.77–2.51
	≥ ½ the time	1.17	0.74–1.86	1.87	1.02–3.45
Arms extended when lift ended	Less than ½ the time	1.08	0.69–1.71	1.63	0.90–2.94
	≥ ½ the time	1.08	0.67–1.74	1.57	0.84–2.92
Twisted while lifting	Less than ½ the time	0.98	0.66–1.45	1.43	0.85–2.41
	≥ ½ the time	1.35	0.74–2.47	1.90	0.92–3.93

*Adjusted for race, education, and current smoking habits.
†Referent group for all comparisons is those who did not lift ≥ 25 lb inanimate objects off the job.

Table 4. Estimated Relative Risk (RR) and 95% Confidence Intervals (95% CI) for Association Between Lifting 10–24 and 25 or More Pound Children in the Two Years Before Health Problem Began and Herniated Lumbar Disc for All Cases Combined (n = 287) and for 25+ Pound Children Among Confirmed Cases Only (n = 177)*

		10–24 lb		25+ lb			
		All Cases		All Cases		Confirmed	
Variable	Variable Category†	RR	95% CI	RR	95% CI	RR	95% CI
Lifted child at least once/wk for 6 mo	Yes	0.96	0.65–1.40	1.10	0.74–1.64	1.00	0.61–1.65
How lifted from floor	Knees bent, back straight	0.65	0.37–1.15	0.76	0.44–1.30	0.66	0.34–1.31
	Knees bent, back bent	0.40	0.16–0.97	1.06	0.43–2.62	1.03	0.38–2.79
	Knees straight, back bent	1.62	0.95–2.78	1.95	0.94–4.05	1.93	0.73–5.06
Level started lift	Floor/knee	0.85	0.56–1.29	0.91	0.56–1.47	0.83	0.46–1.48
	Waist or higher	1.32	0.67–2.61	1.83	0.92–3.64	2.03	0.77–5.33
Level ended lift	Floor/knee	0.87	0.43–1.77	0.99	0.48–2.05	0.84	0.37–1.94
	Waist or higher	0.97	0.64–1.47	1.14	0.73–1.79	1.09	0.60–1.96
Level lift started and ended	Floor to floor	0.63	0.29–1.38	0.72	0.32–1.62	0.70	0.28–1.77
	Floor to waist	0.96	0.60–1.53	1.01	0.59–1.75	0.89	0.44–1.82
	Waist to waist	0.98	0.47–2.05	1.36	0.67–2.75	1.57	0.57–4.34
Arms extended when lift started	Less than ½ the time	0.83	0.46–1.48	1.21	0.70–2.10	1.58	0.80–3.14
	≥ ½ the time	1.07	0.68–1.68	0.97	0.58–1.61	0.61	0.30–1.23
Arms extended when lift ended	Less than ½ the time	1.02	0.63–1.66	1.11	0.68–1.80	1.31	0.71–2.39
	≥ ½ the time	0.93	0.55–1.55	0.95	0.54–1.68	0.52	0.23–1.14
Twisted while lifting	Less than ½ the time	0.96	0.64–1.43	1.00	0.65–1.55	0.99	0.57–1.73
	≥ ½ the time	1.11	0.50–2.43	1.21	0.58–2.53	0.87	0.34–2.24

*Adjusted for race, education, and current smoking habits.
†Referent group for all comparisons is those who did not lift children of specified weight.

95% CI = 0.56–1.23) and among all case subjects for shovelling more than 15 times in that period (RR = 0.68, 95% CI = 0.39–1.20). The associations among confirmed case subjects for bending and shovelling were of a similar magnitude to associations for all case subjects combined.

■ Discussion

In this study, lifting with the knees straight and back bent was consistently associated with herniated lumbar disc, including among those lifting objects weighing 25 lb or more, children weighing 10–24 lb, and children weighing 25 lb or more. This lifting position increased the risk for confirmed disc herniation nearly fourfold when 25 or more pound inanimate objects were lifted. The association between lifting with knees straight and back bent and risk of herniated disc was also seen among those who lifted on the job.[23] Such results are consistent with biomechanical studies indicating increased disc pressure and intra-abdominal pressure when lifting with the knees straight and back bent.[5–7,10,12–15,19,20] Some studies find only small amounts of increased intra-abdominal pressure differences between lifting with the knees straight and back bent compared to lifting with the knees bent and back straight;[36,39,46] intra-abdominal pressure differences become greater for the former position if the arms are extended,[6,7,36,37] if greater amounts of weight are lifted[5,39] or if the lift is done in two stages.[46] Others[7,22,36,37,41] generally conclude that the benefits of lifting with the knees bent and back straight are only seen when the load can be lifted close to the body, preferably between the knees. Most recently, results of a study evaluating lifting technique with respect to trunk muscle and lumbar ligament contribution indicated risk of injury may be more a function of degree of lumbar flexion than choice of lifting technique.[42]

Based on biomechanical principles, the compression on the spine increases with increasing weight lifted;[5,49] it is likely that the risk of herniation is less when lighter weights are lifted. Among lifters of children weighing 10–24 lb, no association between lifting and herniated disc was found for confirmed case subjects, providing support that lighter weights are less detrimental.

The higher relative risk for lifting with the knees straight and back bent associated with confirmed case subjects (RR = 3.95) compared to unconfirmed case subjects (RR = 0.49) suggests that the association is specific to herniated disc. The strength of this finding in the confirmed case subgroup as compared to the unconfirmed subgroup is unlikely to have occurred because of cases "explaining" their problem by attributing the cause to a method of lifting; under that assumption, the same strong positive association would have also been seen among the unconfirmed cases. Additionally, it is unlikely that reporting of lifting method was biased, that is, reported differentially by subjects based on their case status, as replicate findings with respect to lifting position were found for three separate lifting circumstances reported in the interview (occupational lifting, history of lifting, and lifting off the job, both inanimate objects and children). As persons responding positively in each of the questionnaire sections concerned with lifting were not necessarily the same, it is unlikely that these same results would have been seen if the respondents were recalling in a biased manner. Also, in this study, an objective measure of lifting objects on the job, as described in the Dictionary of Occupational Titles,[47,48] was assigned to occupational titles reported in the interview.[23] The agreement between measures of activities established for specific occupations listed in the Dictionary of Occupational Titles and the interview responses for similar activities was good among both case and control subjects. This indicates that, at least for occupational lifting, the subjects were not likely to alter responses to questions concerning lifting to reflect what they felt might be causing their condition. This reasoning may apply to the non-occupational data as well.

Use of a questionnaire to obtain information about risk factors, rather than observing the study subjects, was the only practical way to obtain these data. As the study was concerned with numerous behaviors and activities during daily life, it would have been prohibitively costly and excessively inconvenient to observe all activities. Although some incorrect reporting in the interview undoubtedly occurred, random recall inaccuracies by case and control subjects can only attenuate, not increase, the magnitude of true associations.

Findings related to other aspects of lifting, such as lifting with arms extended or twisting while lifting were not as consistent nor as strong as might be expected based on biomechanical[7,43,49] and previous epidemiologic[32] evidence, although the associations were most strongly associated with increased risk among the confirmed case subjects. Lifting with arms extended has been shown to increase disc pressure and spinal compression in experimental studies[6,7,49] and would be expected to be identified as a risk factor for herniation in an epidemiologic study. However, it is possible that the questions pertaining to lifting with arms extended did not accurately assess this motion. Results from several biomechanical studies have shown that torsion is not associated with initiation of disc degeneration.[2,4,17,38,44] The inconsistent and weak associations for twisting while lifting off the job may indicate this activity is less frequent or less accurately remembered than when more habitual occupational activity is considered.

The amount smoked in the year before the health problem began showed a strong association with herniated lumbar disc. Results from this study add to the growing literature showing an association between disc disease and smoking.[8,9,16,25,30,31] Experimental evidence supporting this association suggests that smoking decreases the diffusion of nutrients to the disc[27] and that nutrient flow increases with cessation of smoking. Although there is not direct evidence of smoking causing herniation, this experimental evidence provides biological plausibility. It has also been hypothesized that excess coughing among smokers may result in mechanical stresses associated with back pain,[21] as well as increased disc pressure.[40]

No associations with other non-occupational activities such as bending, stretching or carrying were shown, although biomechanical studies have shown associations with bending, particularly with compression.[1,3,24] However, the negative association with increased shovelling was unexpected. It is possible that some case subjects experienced mild episodes of low back pain before the reported date of symptom onset, resulting in a decrease in some non-essential activities, such as shovelling. This would appear as a "protective" effect for shovelling. Alternatively, it is possible that control subjects were more fit and were more likely to engage in this activity. Results are equivocal, however, concerning fitness and protection against back pain.[11,45]

A potential weakness of the study was inclusion of unconfirmed case subjects. A small number of unconfirmed case subjects had positive symptomatology but a negative radiology report (computed tomographic scan, magnetic resonance imaging, myelogram). However, for most unconfirmed case subjects these diagnostic procedures had not been performed, especially for those identified through emergency rooms.

The generally stronger association among confirmed case subjects as compared to all case subjects strengthens the evidence for reported associations with herniated disc specifically.

Because control subjects were more likely than case subjects to be white and had more years of education, the question of whether the control group was appropriate needs to be addressed. If the control subjects were different from the case subjects only with respect to race and education, adjustment for these variables in the analysis would control for the apparent differences in the study groups. If there were other differences not measured in this study, then bias when comparing case subjects to control subjects could remain. The choice of orthopaedic controls for private practice case subjects was most appropriate for this study design, because it was expected that both case and control subjects seen in the practices would represent the same source population. However, particularly with orthopaedic practices, individual physician or practice specialties, such as sports injuries, might draw certain patients with conditions other than herniated disc who would not necessarily seek care at these practices if they had experienced back pain. With participation of all orthopaedic surgeons and neurosurgeons from each of the major practices at each study site, the problem of physician specialty should be lessened. Additionally, when patients who had been seen for sports injury, whether case or control subject, were removed from analysis, results were not significantly different. Actual referral patterns for control subjects, had they become case subjects, can remain only subject to speculation; thus, we cannot be certain that case and control subjects are comparable in all ways that might influence the study results.

In conclusion, if results presented are confirmed by other investigators, prevention of herniated lumbar disc through education in lifting techniques and evaluation through intervention studies should be extended beyond the workplace and into the home as well. Lifting 25 or more pounds with the knees bent and back straight and not extending the arms or twisting during the lift may be justifiable precautions, given these and other data. Such modifications would be particularly important among young adults, in view of the impact of activity limitation if disc herniation occurs. The association with smoking is interesting and deserves consideration in future studies of herniated disc. We suggest that further research in the epidemiology of herniated disc include only confirmed case subjects, even though some true cases may be missed because of apparent negative radiology or lack of radiology. Such case restriction would increase the likelihood of establishing associations specifically with herniated disc, and would reduce the dilution of the magnitude of associations when several back disorders of possible different etiology are combined.

References

1. Adams MA, Hutton WC: Gradual disc prolapse. Spine 10:524–531, 1985
2. Adams MA, Hutton WC: The relevance of torsion to the mechanical derangement of the lumbar spine. Spine 6:241–255, 1981
3. Adams MA, Hutton WC: Prolapsed intervertebral disc. A hyperflexion injury. Spine 7:184–191, 1982
4. Ahmed AM, Duncan NA, Burke DL: The effect of facet geometry on the axial torque-rotation response of lumbar motion segments. Spine 15:391–401, 1990
5. Anderson CK, Chaffin DB: A biomechanical evaluation of five lifting techniques. Applied Ergonomics 17:2–8, 1986
6. Andersson BJG, Örtengren R, Nachemson A: Quantitative studies of back loads in lifting. Spine 1:178–185, 1976
7. Andersson G, Örtengren R, Nachemson A: Quantitative studies of the load on the back in different working postures. Scand J Rehabil Med (Suppl) 6:173–181, 1978
8. Battie MC, Bigos SJ, Fisher LD, et al: A prospective study of the role of cardiovascular risk factors and fitness in industrial back pain complaints. Spine 14:141–147, 1989
9. Battie MC, Videman T, Gill K, et al: Smoking and lumbar intervertebral disc degeneration: an MRI study of identical twins. Spine 16:1015–1021, 1991
10. Bendix T, Eid SE: The distance between the load and the body with three bi-manual lifting techniques. Applied Ergonomics 14:185–192, 1983
11. Biering-Sorensen F: Physical measurements as risk indicators for low-back trouble over a one-year period. Spine 9:106–119, 1984
12. Cailliet R: Low Back Pain Syndrome. Fourth edition. Philadelphia, F. A. Davis Co., 1988
13. Davis PR: The causation of herniae by weight-lifting. Lancet ii:155–157, 1959
14. Davis PR: Posture of the trunk during the lifting of weights. Br Med J 1:87–89, 1959
15. Davis PR, Troup JDG: Pressures in the trunk cavities when pulling, pushing and lifting. Ergonomics 7:465–474, 1964
16. Deyo RA, Bass JE: Lifestyle and low back pain: The influence of smoking and obesity. Spine 14:501–506, 1989
17. Duncan NA, Ahmed AM: The role of axial rotation in the etiology of unilateral disc prolapse: An experimental and finite-element analysis. Spine 16:1089–1098, 1991
18. EGRET: Epidemiological Graphics, Estimation and Testing Package. Version 0.23.21; Epixact, version 0.02, 1989
19. Eie N: Load capacity of the low back. J Oslo City Hosp 16:73–98, 1966
20. Eie N, Wehn P: Measurements of the intra-abdominal pressure in relation to weight bearing of the lumbosacral spine. J Oslo City Hosp 12:205–217, 1962
21. Frymoyer JW, Pope MH, Costanza MC, et al: Epidemiologic studies of low back pain. Spine 5:419–423, 1980
22. Garg A, Herrin GD: Stoop or squat: A biomechanical and metabolic evaluation. AIIE Trans 11:293–302, 1979
23. Golden AL: Occupational physical demands and risk of prolapsed lumbar intervertebral disc. (Dissertation). Columbia University. New York, NY, 1991
24. Gordon SJ, Yang KH, Mayer PJ, et al: Mechanism of disc rupture. A preliminary report. Spine 16:450–456, 1991
25. Heliovaara M: Epidemiology of sciatica and herniated lumbar intervertebral disc. Publications of Social Insurance Institution, Finland, ML76. Helsinki, Finland, 1988

26. Heliovaara M, Knekt P, Aromaa A: Incidence and risk factors of herniated lumbar intervertebral disc or sciatica leading to hospitalization. J Chronic Dis 40:251–258, 1987
27. Holm S, Nachemson A: Nutrition of the intervertebral disc: Acute effects of cigarette smoking. An experimental animal study. Ups J Med Sci 93:91–99, 1988
28. Kelsey JL: An epidemiological study of acute herniated lumbar intervertebral discs. Rheumatol Rehabil 14:144–159, 1975
29. Kelsey JL: An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. Int J Epidemiol 4:197–205, 1975
30. Kelsey JL, Githens PB, O'Conner T, et al: Acute prolapsed lumbar intervertebral disc: An epidemiologic study with special reference to driving automobiles and cigarette smoking. Spine 9:608–613, 1984
31. Kelsey JL, Githens PB, Walter SD, et al: An epidemiologic study of acute prolapsed cervical intervertebral disc. J Bone Joint Surg 66A:907–914, 1984
32. Kelsey JL, Githens PB, White AA, et al: An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. J Orthop Res 2:61–66, 1984
33. Kelsey JL, Greenberg RA, Hardy RJ, Johnson MF: Pregnancy and the syndrome of herniated lumbar intervertebral disc: An epidemiologic study. Yale J Biol Med 48:361–368, 1975
34. Kelsey JL, Hardy, RJ: Driving of motor vehicles as a risk factor for acute herniated lumbar intervertebral disc. Am J Epidemiol 102:63–73, 1975
35. Kelsey JL, Ostfeld AM: Demographic characteristics of persons with acute herniated lumbar intervertebral disc. J Chronic Dis 28:37–50, 1975
36. Leskinen TPJ, St Ihammar HR, Kuorinka IAA, Troup JDG: A dynamic analysis of spinal compression with different lifting techniques. Ergonomics 26:595–604, 1983
37. Lindh M: Biomechanics of the lumbar spine. Chapter 10. Biomechanics of the Skeletal System. Edited by V Frankel, M Nordin. Philadelphia, Lea & Feibiger, 1980, pp 255–290
38. Liu YK, Goel K, DeJong A, et al: Torsional fatigue of the lumbar intervertebral joints. Spine 10:894–900, 1985
39. Morris JM, Lucas DB, Bresler B: Role of the trunk in stability of the spine. J Bone Joint Surg 43A:327–351, 1961
40. Nachemson A: Low back pain—Its etiology and treatment. Clin Med 78:18–24, 1971
41. Park KS, Chaffin DB: A biomechanical evaluation of two methods of manual load lifting. AIIE Trans 6:105–113, 1974
42. Potvin JR, McGill SM, Norman RW: Trunk muscles and lumbar ligament contributions to dynamic lifts with varying degrees of trunk flexion. Spine 16:1099–1107, 1991
43. Shirazi-Adl A: Strain in fibers of a lumbar disc. Analysis of the role of lifting in producing disc prolapse. Spine 14:96–103, 1989
44. Shirazi-Adl A, Ahmed AM, Shrivastava SC: Mechanical response of a lumbar motion segment in axial torque alone and combined with compression. Spine 11:914–927, 1986
45. Troup JDG: Causes, prediction and prevention of back pain at work. Scand J Work Environ Health 10:419–428, 1984
46. Troup JDG, Leskinen TPJ, St Ihammar HR, Kuorinka IAA: A comparison of intraabdominal pressure increases, hip torque and lumbar vertebral compression in different lifting techniques. Hum Factors 25:517–525, 1983
47. U.S. Department of Labor: Employment and Training Administration. Dictionary of Occupational Titles. Fourth Edition. Washington, DC: U.S. Government Printing Office, 1977
48. U.S. Department of Labor: Employment and Training Administration. Selected Characteristics of Occupations Defined in the Dictionary of Occupational Titles. Washington, DC: U.S. Government Printing Office, 1981
49. White AA, Panjabi MM: Clinical Biomechanics of the Spine. Second edition. Philadelphia, JB Lippincott, 1990

Address reprint requests to

Diane J. Mundt, PhD
National Academy of Science
Institute of Medicine (FO 3088)
2101 Constitution Ave., NW
Washington, DC 20418