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Relationship between alterations of the lumbar spine, visualized with magnetic resonance imaging, and occupational variables

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Abstract Although the effect of physical workload on the occurrence of low back pain (LBP) has been extensively investigated, few quantitative studies have examined the morphological changes visualized via magnetic resonance imaging (MRI) in relation to occupational variables. The relationship between the severity of some abnormalities such as lumbar spinal stenosis or spondylolisthesis and physical or psychosocial occupational risk factors has not been investigated previously. In this cross-sectional study patients fulfilled the following inclusion criteria: (1) long-standing (minimum 1-year) LBP radiating down the leg (or not); (2) age more than 40 years; (3) willingness to undergo an MRI of the lumbar spine; and (4) ability to speak Italian. Primary objective of the study was to investigate the association between occupational exposure and morphological MRI findings, while controlling for the individual risk factors for LBP. Secondarily, we looked at the influence of this exposure and the degenerative changes in the lumbar spine on clinical symptoms and the related disability. Lumbar MRI scans from 120 symptomatic patients were supplemented by the results of structured interviews, which provided personal, medical, and occupational histories. All occupational factors were arranged on scales of increasing exposure, whereas pain and disability were assessed using ad hoc validated questionnaires. Evidence of intervertebral disc narrowing or herniation and the occurrence and severity of spinal stenosis and spondylolisthesis was obtained from the MRI scans and a summative degenerative score was then calculated. We detected a direct association between increasing age and the global amount of degenerative change, the severity of intervertebral disc height loss, the number of narrowed discs, stenosis, the number of stenotic levels, and spondylolisthesis. Physical occupational exposure was not associated with the presence of lumbar disc degeneration and narrowing per se, but a higher degree of such an exposure was directly associated with a higher degree of degeneration ($P = 0.017$). Spondylolistesis and stenosis were positively related to heavy workload ($P = 0.014$) and the manual handling of materials ($P = 0.023$), respectively. Psychosocial occupational discomfort was directly associated to stenosis ($P = 0.041$) and number of stenotic levels ($P = 0.019$). A heavier job workload was the only occupational factor positively related to the degree of disability at the multivariate analysis ($P = 0.002$). Total amount of degeneration in the lumbar spine directly influenced pain duration ($P = 0.011$) and degree of disability ($P = 0.050$). These results suggest that caution should be exercised when symptomatic subjects with evidence of degenerative changes on MRI scans engage in strenuous physical labor.

Keywords Lumbar spine · Spinal stenosis · Spondylolisthesis · Occupational exposure · Magnetic resonance imaging

Introduction

The effect of the physical load at work on the occurrence of low back pain (LBP) has been widely studied during the past 30 years. The main causes of back problems in the workplace include heavy lifting, loads on the spine from the manual handling of materials, prolonged static postures, awkward postures inducing postural stress, and whole body vibration associated with driving [4, 34]. The number of epidemiological studies that have dealt with psychosocial risk factors during work is considerably smaller than the number looking at physical load. Hoogendoorn et al. [23] have reviewed the relationship between psychosocial factors and back pain and found evidence for the detrimental effect of low workplace social support and low job satisfaction. Moreover, there are significant relationships between low back disorders and some individual risk factors such as aging [9], socioeconomic status [31], educational level [12], smoking [9, 17, 18, 38], gender [47], anthropometric measures [19, 29], and physical activity [6]. Evidence of a family predisposition toward lumbar degenerative disc disease and LBP has also been reported [36, 39]. Some of these individual factors can be confounded with employment history (length and type of work) [14]. Work-related symptoms and disability have been hypothesized to be secondary to the mechanical factors that lead to structural damage to the lumbar spine [44]. Unlike the above correlation with clinical symptoms, few studies have investigated the physical damage related to occupational exposure and most of these have focused exclusively on the lumbar intervertebral disc [3, 32]. Here, we were primarily interested in the association between occupational exposure and morphological magnetic resonance imaging (MRI) findings, while controlling for the individual risk factors for LBP. Secondarily, we looked at the influence of this exposure and the degenerative changes in the lumbar spine on clinical symptoms and the related disability.

Materials and methods

This cross-sectional study was conducted between January 2001 and September 2003, in the orthopaedic surgery departments of the Naples “Federico II” and Catanzaro “Magna Graecia” University hospitals in Italy. Participants enrolled in Catanzaro are from a prevalently rural district with nearly 400,000 inhabitants in the far South of Italy. Patients enrolled in Naples live in a large metropolitan area with nearly 3,000,000 inhabitants. Both participating departments have public spine surgery outpatient clinics that receive patients with different socioeconomic, occupational, and antrhropometric characteristics, who are worthy sample of the entire population in the uptake area. In each department we enrolled patients, attending the outpatient clinic or hospitalized, who fulfilled the following inclusion criteria: (1) long-standing (minimum 1-year) LBP radiating down the leg (or not); (2) age more than 40 years [33]; (3) willingness to undergo an MRI of the lumbar spine; and (4) ability to speak Italian. Exclusion criteria included: (1) age less than 40 years, (2) secondary causes of LBP (tumour, infection, congenital anomaly, trauma, psoriasis, chronic polyarthritis, osteoporosis), and (3) previous back surgery. The design was approved by the two hospitals’ respective ethics committees. After application of the exclusion criteria, 143 patients were eligible for the study. Twenty-three of them (16%) refused to participate, leaving 120 subjects available for the study. There were no missing data for any patient. The participants were 72 females (60%) and 48 males (40%) and the mean age was 57.5 ± 11.8 years (range 40–84). After informed consent was obtained from each, the subjects’ weight and height were recorded.

Interview

All the participants then underwent a structured interview to obtain their personal, medical, and occupational histories.

Personal data included information on educational level, smoking habits, and the practice of sport. Educational level was recorded on a five-step scale from Grade 1 (no school attendance) to Grade 5 (graduation). The data on smoking included questions on the number of cigarettes smoked per day and duration of the habit. Physically active patients were classified as engaged in strenuous sports, or not. Patients that were qualified for a national competition during their lifetime sport practice were considered as having been engaged in a strenuous sport.

Quantitative and qualitative data for occupational exposure were obtained by asking the participants to report the duration and characteristics of every job they had held since they began working. Lifetime work exposure was calculated by multiplying working hours per day by 220 work days per year by total years of every job held [3]. Finally, the totals for each job were summed. To obtain the qualitative information, physical and psychosocial work-related risk factors were considered. Self-perception of a heavy workload, manual handling of materials (including lifting, moving, carrying, and holding loads), awkward postures, static sitting or standing work posture, and occupational driving exposure were selected as important physical factors. Following Videman et al. [46], every job was assigned to one of the four categories on the basis of materials-handling activities and awkward postures as follows: load weight (from up to 5 to more than 36 kg) and frequency of handling (less or more than ten times per day) were together used to obtain a five-point subscale. Frequency of bending or twisting, evaluated by another five-point subscale ranging from "never" to "very often", was assigned five more points. Thus, the maximum possible score on the whole scale was ten points. Subjects scoring three points or less were placed in Category One (sedentary or light workload), subjects scoring three to five points in Category Two, subjects scoring five to seven points in Category Three, and subjects with more than seven points in Category Four (heavy workload). In case of multiple jobs, the score on the scale was assigned on the basis of the proportional contribution of each job with different work hardness to the whole lifetime workload. Static work posture was investigated through questions on the time spent every day in a sitting or standing position, with five-item scales ranging from "never" to "more than 6 h/day". Occupational driving exposure was also evaluated asking participants whether they spent time during the day in motorized vehicles for professional purposes. If so, they were queried about the duration of their occupational driving and the mean number of hours per day spent driving. The lifetime occupational driving exposure was calculated as in Battié et al. [3]. Finally, participants were asked to recall whether they had incurred any back injuries during their work.

For the medical history, participants were asked to recall the time elapsed since their first episode of LBP. An episode of LBP was defined as pain, ache, stiffness, or fatigue localized to the lower back, with or without radiating pain/ache in one or both legs [37], lasting few hours at least. To decrease the recall bias, the patients were asked to report episodes of their usual pain [27]. The occurrence of back problems in first degree relatives was also noted. A relative was considered to have a positive history if he or she had sought some kind of medical care for LBP and/or leg pain, or if there had been pain sufficient to limit daily activities [36].

Questionnaires

All participants completed two questionnaires: the Oswestry Low Back Pain Disability Questionnaire (a reliable ten-item tool to assess the disability resulting from LBP [15]) and a questionnaire to distinguish patients with discogenic LBP from patients with LBP from other causes [39]. The latter was validated by the authors themselves [39] and was proven to be sensitive and specific for the detection of the discogenic nature of LBP. It consists of two sections, the first including questions on basic demographic information, medical history, and symptoms, and the second section dealing with the frequency of activities known to be associated with lumbar disc injuries (i.e., bending over the sink, driving, coughing, sneezing, etc.). A total score equal to or greater than 26 points (maximum possible score = 43 points) indicates highly probable lumbar disc injury and pain.

A specific questionnaire was used to investigate occupational and extra-occupational psychosocial risk factors [22]. This questionnaire consisted of 31 items on psychosocial occupational discomfort, with a five-point response scale ranging from "never" to "very often". Answers were grouped into ten multi-item and three single-item domains expressing several psychosocial factors. Using the results of some studies [22, 23] the domains of quantitative demand, anxiety for health, psychic symptoms, psychosomatic symptoms, job satisfaction, and stress were used to create a seven-step scale of increasing self-reported psychosocial occupational discomfort. In case of positive response one point was assigned to each domain. Thus, the scale ranged from 0 (no reports for any domain) to 6 (all the psychosocial domains were reported) points.

MRI assessment

Posteroanterior and lateral radiographs and an MRI examination of the lumbosacral spine were obtained from all subjects. MRI scans were performed with a GE Vectra scanner (Milwaukee, WI). T1-weighted (Spin echo, TR 550, TE 25) and T2-weighted (Gradient echo, TR 700, TE 30) sagittal sections, as well as T2-weighted transverse images (Gradient echo, TR 650, TE 30, slice thickness 4 mm) were obtained at 0.5 tesla. Scans performed at each intervertebral space from L1/L2 to L5/S1 were selected. MRI images were digitized and the graphic files were transformed in vectorial files. Therefore, the dural sac cross-sectional area at the most stenotic level was calculated by means of an Autocad software (Autodesk, San Rafael, CA). Following Schönström et al. [42], a level was considered to be stenotic if the dural sac cross-sectional area was less than 100 mm^2. The total amount of degeneration in the lumbar spine was calculated on a summative degenerative scale (SDS) [21]. On the SDS, points are assigned for each level to the following: disc degeneration (0 = normal disc, 1 = degenerated disc. An intervertebral disc was considered to be degenerated when it showed intensity less than that of the adjacent cerebrospinal fluid or when there was a bulging on T2 weighted images [2]); height of disc (0 = height more than 10 mm, 1 = height of 5–9 mm, 2 = height of 4 mm or less); facet arthritis (one point for each arthritic joint); disc herniation (an intervertebral disc was considered to be herniated when it protruded or was extruded, following Jensen et al. [26]); and degenerative spondylolisthesis (one point for each millimeters of vertebral slippage; the amount of slipping was calculated by measuring the distance from a line parallel to the posterior portion of the first sacral vertebral body to a line drawn parallel to the posterior portion of the body of the fifth lumbar vertebra [7]). All measurements were performed in duplicate by two different neuroradiologists who were unaware of the occupational and clinical characteristics of the patients. A consensus decision on the scores of all MRI changes was reached in a final common readout. Test–retest reliability was assessed using a subset of 20 examinations on which all parameters were evaluated and scored twice on two separate days. The interobserver agreement (kappa value) between neuroradiologists varied from 0.58 to 0.86 for the anomalies included in the SDS, whereas the intraobserver agreement varied from 0.61 to 0.90.

Statistical analysis

A two-sample *t*-test was used when appropriate. An analysis of variance was used to test the differences among multiple groups. The differences were checked by Bonferroni tests. A Chi-square test was used to assess the significance of differences between categorical variables. Non-parametric methods were used for variables not normally distributed. Univariate and backward stepwise linear regression analyses were used to determine whether the work-related variables were significantly associated with the Oswestry Questionnaire score or the duration of pain in months, which were treated as continuous variables. The occurrence of pain of discogenic origin as an outcome was examined by univariate and multiple logistic regression analyses, using a dichotomous variable based on the questionnaire for discogenic pain ($0 \leq 26$ points; $1 \geq 26$ points). Models of backward stepwise linear and logistic regression analysis were used to assess the correlations between occupational exposure factors and morphological outcomes with continuous and categorical distributions, respectively. Separate models were also created to check possible relationships of Oswestry Questionnaire score, duration of pain, and discogenic pain with the degenerative changes. The outcomes inserted in the model were SDS (continuous), presence of stenosis (categorical), number of stenotic levels (continuous), presence of spondylolisthesis (categorical), degree of slipping in millimeters (continuous, only in subjects with spondylolisthesis), evidence of a narrowed intervertebral disc (categorical), number of discs reduced in height (continuous), height of the narrowest disc (categorical, only in subjects with narrowed discs), presence of disc herniation (categorical), and number of herniated discs (continuous). In each patient, SDS score and single degenerative changes were treated as outcome variables for separate models of regression analysis. The occupational and confounding explanatory variables included in the models were age (continuous), gender (categorical: 0 = female; 1 = male), family predisposition (categorical: 0 = no; 1 = yes), body mass index (BMI)(continuous), educational level scale (ordinal), smoking (categorical: 0 = no; 1 = yes), practice of sports (categorical: 0 = no; 1 = yes), job category scale (ordinal), self-perception of a heavy workload (categorical: 0 = no; 1 = yes), lifetime working exposure (continuous), manual loadhandling (categorical: 0 = no; 1 = yes), load weight (ordinal), frequency of task (ordinal), awkward occupational posture (ordinal), prolonged occupational sitting posture (ordinal), prolonged occupational standing posture (ordinal), occupational driving exposure (categorical: 0 = no; 1 = yes), previous occupational trauma (categorical: 0 = no; 1 = yes), and self-reported professional psychosocial occupational discomfort scale (ordinal). Because of the small number of patients having been engaged in strenuous sports, this variable was not evaluated in the statistical analysis. Before constructing the models age-adjusted univariate linear and logistic regression analyses were performed. All explanatory variables were included in our multiple regression models independent of their significant association with the outcome of interest in the univariate analysis. First, backward regression analysis was used in order to keep the regression models as simple as possible reducing the number of regressor variables. All explanatory variables were included in the model and then if the partial sum of squares for any previously included variables did not meet a minimum criterion to stay in the model, the terms were dropped one at a time until all remaining variables met the minimum criterion. Later, these latter explanatory variables only were included again one at a time in the model to evaluate the contribution of the single terms in the variation in the interaction margin. In multiple linear regression analysis, total R^2 for the model and changes in R^2 for the independent contribution of single occupational exposures were calculated to assess the percent of total variance in the outcome variable accounted for by the whole model and single explanatory variables, respectively. In multiple logistic regression, log-likelihood ratio tests were obtained to evaluate the fit of the model after single predictors were removed. $P \leq 0.05$ was considered significant. Data were analyzed using SPSS software (Statistical Program for Social Science, v. 8.0 for Windows, SPSS, Evanston, IL).

Results

The characteristics of the 120 study subjects are shown in Table 1. Occupational workload and psychosocial risk factors are reported in Table 2. MRI ratings for each morphologic change in the lumbosacral spine are summarized in Table 3. We did not observe significantly different mean values in dural sac cross-sectional area at the most stenotic level (*F* test = 1.231, *P* = 0.302) or in SDS score (*F* test = 1.052, *P* = 0.372) when subjects from increasing job workload categories were compared using an analysis of variance. The Chi-square tests failed to show significantly different frequency of stenosis, spondylolisthesis, disc narrowing, or disc hermiation when persons with different workload were compared. However, we found a tendency toward a smaller dural sac cross-sectional area at the most stenotic level (99 vs. 117 mm^2, *P* = 0.071), higher value of SDS score (9.09 vs. 7.83, *P* = 0.097), and higher frequency of spondylolisthesis (*P* = 0.055) in subjects reporting a heavy workload. We observed significantly higher Oswestry disability scores as workload category increased (*F* test = 3.757, *P* = 0.013). A Bonferroni test revealed a significant difference between workload categories 1 and 4 (*P* = 0.015) and a trend toward a difference between workload categories 1 and 3 (*P* = 0.065). A tendency toward higher disability in subjects with self-reported heavy workload was also noted (*P* = 0.087). Other clinical outcomes failed to reach the required level of significance in subjects from different professional categories or in those reporting a heavy workload.

Regression analysis

Univariate analysis

Pain and disability When we performed a linear regression analysis in subjects with occupational manual materials-handling, the increasing task frequency was associated with higher Oswestry disability scores [coefficient (*c*) = 13.80; 95% confidence interval (CI) = 1.87–25.74; *P* = 0.024], whereas the load weight was not. A longer pain duration was positively associated with increasing age (*c* = 3.89; 95% CI = 1.68–6.10; *P* = 0.001) and some occupational factors such as prolonged standing posture (*c* = 19.20; 95% CI = 1.19–37.20; *P* = 0.037) and psychosocial occupational discomfort (*c* = 20.03; 95% CI = 3.61–36.44; *P* = 0.017). In the univariate logistic regression analysis, a condition of discogenic pain was positively related to psychosocial occupational factors [odds ratio (OR) = 1.43; 95% CI = 1.09–1.87; *P* = 0.009) and negatively related to prolonged standing as an occupational posture (OR = 0.76; 95% CI = 0.57–0.99; *P* = 0.046). We also saw a tendency toward a direct association with family predisposition (OR = 2.34; 95% CI = 0.91–6.02; *P* = 0.077).

When the possible relationship of degenerative changes with pain and disability was checked at the univariate analysis, the only significant direct association with Oswestry disability score was found for SDS score (*c* = 1.03; 95% CI = 0.05–2.02; *P* = 0.040). As for the pain duration it was directly related to age (*c* = 3.89; 95% CI = 1.68–6.10; *P* = 0.001), SDS score (*c* = 7.13;

Table 1 Characteristics of the study group

Age, year [mean ± standard deviation (SD)]	57.5 ± 11.8
Gender	
Female	72 (60)
Male	48 (40)
BMI, kg/m^2 (mean ± SD)	27.2 ± 3.9
Educational level	
Illiteracy	10 (8.3)
Primary school	56 (46.7)
Secondary school	30 (25)
High school	18 (15)
Graduation	6 (5)
Current occupational status	
Working	63 (52.5)
Housewife	29 (24.2)
Retired	25 (20.9)
Disabled	3 (2.5)
Smoking	
No	67 (55.8)
Yes	53 (44.2)
Cigarettes smoked per day	23 ± 15
Smoking duration (years) (mean ± SD)	21.6 ± 8.1
Practice of sport	
No	92 (76.6)
Yes	28 (23.3)
If yes, strenuous?	
No	23 (82.1)
Yes	5 (17.9)
Family predisposition	
No	32 (26.7)
Yes	88 (73.3)
Pain episodes	6 ± 3.3
Pain, duration (months) (mean ± SD)	140.2 ± 134
Oswestry Questionnaire score (mean ± SD)	43.8 ± 21.9
Discogenic pain	
No	54 (45)
Yes	66 (55)

Values other than mean ± SD represent *n* (%)

Table 2 Occupational exposure of the study group

	n (%)
Manual materials-handling	
No	53 (44.2)
Yes	67 (55.8)
If manual materials-handling yes, load weight (kg)?	
1–5	8 (11.9)
6–10	16 (23.9)
11–20	14 (20.9)
21–35	5 (7.5)
> 36	24 (35.8)
If manual materials-handling yes, task frequency (times/day)?	
< 10	20 (29.9)
> 10	47 (70.1)
Self-reported heavy workload	
No	54 (45)
Yes	66 (55)
Awkward occupational posture	
Never	41 (34.1)
Seldom	24 (20)
Often	32 (26.7)
Very often	23 (19.2)
Workload category	
1	45 (37.5)
2	23 (19.2)
3	18 (15)
4	34 (28.3)
Static work, prolonged sitting	
Never	60 (50)
< 2 h/day	33 (27.5)
2–4 h/day	10 (8.3)
4–6 h/day	6 (5)
> 6 h/day	11 (9.2)
Static work, prolonged standing	
Never	42 (35)
< 2 h/day	39 (32.5)
2–4 h/day	16 (13.3)
4–6 h/day	8 (6.7)
> 6 h/day	15 (12.5)
Occupational driving	
No	106 (88.3)
Yes	14 (11.7)
If occupational driving yes, lifetime occupational driving?	17671 ± 20258.3
Occupational psychosocial risk factors	
0	2 (1.7)
1	12 (10)
2	29 (24.2)
3	31 (25.8)
4	15 (12.5)
5	22 (18.3)
6	9 (7.5)
Previous occupational trauma	
No	72 (60)
Yes	48 (40)

Values other than *n* (%) represent mean ± SD

95% CI = 0.81–13.44; *P* = 0.027), and severity of disc height reduction in subjects with narrowed discs (*c* = 103.73; 95% CI = 25.09–182.38; *P* = 0.010). Negative association with presence of disc herniation (*c* = −58.80; 95% CI = −114.01 to −3.60; *P* = 0.037) and number of herniated levels (*c* = −21.92; 95% CI = −41.28 to −2.5; *P* = 0.027) was detected. In the univariate logistic regression analysis, the presence of discogenic pain was in direct relationship with disc height reduction when only subjects with narrowed discs were considered (OR = 4.32; 95% CI = 1.21–15.34; *P* = 0.024).

Table 3 MRI findings in the study group

Mean dural sac cross-sectional area at the most stenotic level (mm^2) [mean ± SD (range)]	107 ± 49.8 (14–330)
Stenosis	
No	64 (53.3)
Yes	56 (46.7)
Number of stenotic levels	
0	64 (53.3)
1	35 (29.2)
2	14 (11.7)
3	6 (5)
4	1 (0.8)
5	0 (0)
SDS [mean ± SD (range)]	8.6 ± 4.1 (2–23)
Spondylolisthesis	
No	95 (79.2)
Yes	25 (20.8)
Level of spondylolisthesis	
L3	6 (24)
L4	8 (32)
L5	11 (44)
Mean slipping (mm) (mean ± SD)	5.6 ± 1.5
Disc narrowing	
No	22 (18.3)
Yes	98 (81.7)
Number of narrowed discs	
0	22 (18.3)
1	47 (39.2)
2	32 (26.7)
3	11 (9.2)
4	6 (5)
5	2 (1.7)
Height of the narrowest disc (mm)	
5–9	78 (79.6)
≤ 4	20 (20.4)
Disc herniation	
None	39 (32.5)
Protrusion	57 (47.5)
Extrusion	24 (20)
Levels of herniation	
0	39 (32.5)
1	40 (33.3)
2	21 (17.5)
3	12 (10)
4	6 (5)
5	2 (1.7)

Values other than mean ± SD represent *n* (%)

Morphological outcomes The SDS score was positively correlated with increased age (*c* = 0.09; 95% CI = 0.03–0.15; *P* = 0.006) and prolonged standing occupational posture (*c* = 0.71; 95% CI = 0.16–1.25; *P* = 0.011) when we did a univariate regression analysis. Significant inverse association was found with the lifetime working exposure ($c = -0.00004$; 95% CI = −0.00007 to −0.00004; $P = 0.029$). The results of an age-adjusted univariate logistic regression analysis between occupational variables and categorical morphological outcomes are reported in Table 4. Increasing age predicted a condition of lumbar spinal stenosis. The presence of spondylolisthesis was directly associated with manual materials-handling, psychosocial risk factors and, as a tendency, with self-reported heavy workload. Both stenosis and spondylolisthesis were inversely associated with the lifetime working exposure. When we conducted a univariate linear regression analysis, no occupational variables showed significant association with the number of stenotic levels whereas, in subjects with spondylolisthesis, occupational driving was the only factor positively associated with a greater degree of vertebral slipping ($c = 2.79$; 95% CI = 0.75–4.84; $P = 0.010$). No occupational variable was determinant for disc height reduction, but the number of reduced discs was directly related to prolonged occupational standing ($c = 0.20$; 95% CI = 0.05–0.35; $P = 0.010$). The severity of disc height reduction showed tendency toward a positive association with higher job workload category ($c = 0.06$; 95% CI = −0.02 to 0.12; $P = 0.057$) when only subjects with narrowing were considered. As it can be seen from Table 4, the presence of a disc herniation was inversely related to aging, job workload category, and awkward occupational postures, but no occupational exposure was related to more levels of herniation.

Multivariate analysis

Pain and disability When all professional and confounding explanatory variables were inserted in our models of multivariate backward linear regression analysis, a higher job workload category was the only occupational factor that was positively correlated with a subject's Oswestry disability score ($c = 5.42$; 95% CI = 2.08–8.76; $P = 0.002$), whereas the smoking habit was negatively associated to it ($c = -16.96$; 95% CI = −25.55 to −8.36; $P < 0.001$). The model accounted for 22% of total variance in Oswestry disability score, and the job workload category explained 7% of variance. The duration of pain was also directly related to aging ($c = 4.18$; 95% CI = 1.88–6.47; $P = 0.001$) and psychosocial occupational discomfort ($c = 25.12$; 95% CI = 7.44–42.80; $P = 0.006$). This model accounted for 21% in the total variance of pain duration, with psychosocial factors contributing for 7%. A backward multivariate logistic regression analysis revealed that a discogenic origin of the pain was directly associated with the presence of psychosocial occupational risk factors (OR = 2.36; 95% CI = 1.38–4.06; $P = 0.002$) and inversely related to self-reported prolonged standing occupational posture (OR = 0.56; 95% CI = 0.36–0.89; $P = 0.013$).

When we focused on the relationship of degenerative changes in the lumbar spine with pain and disability using models of multivariate linear regression analysis, the Oswestry disability score was in significant association with female gender ($c = -13.84$; 95% CI = −21.58 to −6.09; $P = 0.010$) and SDS score ($c = 0.92$; 95% CI = −0.002 to 1.84; $P = 0.050$). The model accounted for only 15% of total variance in the disability score with female gender being the most important independent factor (13% of total variance). The duration of pain was in direct association with SDS score ($c = 9.38$; 95% CI = 2.21–16.55; $P = 0.011$) and severity of disc height reduction ($c = 104.13$; 95% CI = 30.42–177.84; $P = 0.006$), while it was in negative relationship with the number of herniated discs ($c = -23.39$; 95% CI = −45.64 to -1.13; $P = 0.040$). Severity of disc height reduction and SDS score explained 10 and 8%, respectively, in the total

Table 4 Morphological outcomes: age-adjusted univariate logistic regression analysis

Variable	Stenosis			Spondylolisthesis			Disc narrowing			Disc herniation		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Age	1.04	1.01–1.07	0.023	1.02	0.98–1.06	0.332	1.00	0.96–1.04	0.843	0.95	0.92–0.99	0.006
Lifetime working exposure	0.99	0.99–1.00	0.042	0.99	0.98–1.00	0.003	1.00	0.99–1.00	0.223	1.00	1.00–1.00	0.763
Job workload category	1.12	0.83–1.51	0.458	1.23	0.86–1.76	0.263	0.82	0.56–1.19	0.297	0.69	0.50–0.97	0.032
Self-reported heavy workload	1.05	0.50–2.21	0.899	2.45	0.93–6.45	0.069	0.51	0.19–1.36	0.179	0.49	0.21–1.14	0.099
Manual material handling	1.55	0.74–3.28	0.248	2.65	1.01–6.98	0.049	0.76	0.29–1.95	0.565	0.46	0.20–1.07	0.072
Load weight[a]	1.16	0.82–1.64	0.391	0.75	0.50–1.11	0.115	0.90	0.59–1.38	0.633	0.78	0.53–1.14	0.206
Task frequency[a]	1.47	0.49–4.37	0.493	1.22	0.36–4.13	0.750	0.15	0.02–1.22	0.075	0.73	0.22–2.40	0.608
Awkward occupational posture	0.93	0.67–1.29	0.657	1.16	0.78–1.71	0.469	0.93	0.62–1.40	0.732	0.65	0.45–0.94	0.024
Prolonged occupational sitting	1.07	0.80–1.42	0.663	0.68	0.44–1.07	0.095	1.04	0.72–1.50	0.852	1.13	0.81–1.59	0.463
Prolonged occupational standing	1.07	0.81–1.40	0.653	1.33	0.97–1.83	0.072	1.24	0.85–1.82	0.259	0.86	0.64–1.16	0.331
Professional vehicle driving	2.80	0.80–9.86	0.109	0.64	0.13–3.12	0.583	0.47	0.13–1.68	0.244	1.05	0.29–3.76	0.941
Psychosocial risk factors	1.04	0.81–1.34	0.759	1.44	1.04–1.99	0.027	0.88	0.64–1.21	0.432	0.85	0.64–1.13	0.256
Previous occupational trauma	1.47	0.68–3.16	0.326	1.65	0.67–4.10	0.277	0.46	0.18–1.20	0.113	1.14	0.49–2.65	0.756

[a] Subjects manually handling materials were selected

variance of pain duration, whereas the number of herniated discs accounted for 4%. Finally, the severity of disc height reduction in subjects with narrowed discs was the only degenerative change predicting a condition of discogenic pain at multiple logistic regression analysis (OR = 3.96; 95% CI = 1.20–13.06; P = 0.024).

Morphological outcomes Summary results of the multivariate backward logistic regression analysis for the morphological outcomes are reported in Table 5. Aging was directly associated with stenosis and spondylolisthesis and inversely with the presence of a disc herniation. Occupational manual materials-handling and psychosocial occupational discomfort were directly associated with stenosis as was the self-reported heavy workload for spondylolisthesis. This latter condition was also directly influenced by the sport practice. As for the gender, spondylolisthesis and disc herniation were more frequent in women and men, respectively. Several factors were inversely associated with the morphological outcomes, i.e., life time work exposure with stenosis and spondylolisthesis, awkward postures with stenosis and herniation, prolonged occupational sitting with spondylolisthesis, and BMI with disc herniation. Our multivariate analysis revealed that no factors were directly associated with disc narrowing in this sample, whereas professional vehicle driving was inversely related to it. The analysis of likelihood ratios showed that lifetime working exposure and self-reported heavy workload were the occupational determinants most influencing the fit of models. Summary results of the multivariate backward linear regression analysis for continuous and ordinal morphological outcome variables are reported in Table 6. Several occupational exposures were independently associated with these outcome variables, although they accounted for small percentages in the total variance. In detail, increasing age and a prolonged standing static occupational posture were associated with higher scores on the SDS and more narrowed discs. Aging and family predisposition showed direct influence on the severity of disc height reduction. Male gender and BMI were both related to the levels of disc herniation, the former positively and the latter negatively. The finding of more levels with stenosis was directly related to increasing age, higher job workload category, self-reported heavy workload, and higher psychosocial discomfort, whereas it was in inverse relationship with lifetime workload exposure and awkward occupational postures.

Discussion

The aim of the present study was to look at the relationship between occupational exposure and degenerative changes in the lumbar spine. As a secondary goal, we examined the effect of work-related risk factors on LBP and disability. In this field, valid measurements of both exposure and outcome are needed to satisfactorily assess risk [14, 44]. Several risk factors related to physical aspects of the workplace such as heavy physical work, lifting and forceful movements, awkward posture, professional driving, and static work posture were suggested by the results of previous studies [4, 34]. A specific scale [3, 46], based on manual materials-handling

Table 5 Determinants of morphologic outcomes in multivariate backward logistic regression analysis

Explanatory variables	Morphologic outcomes				
	OR	95% CI	P	−2 Loglikelihood ratio (LR)	P of log LR
Stenosis					
Age	1.07	1.02–1.13	0.005	9.39	0.002
Lifetime working exposure	0.99	0.99–1.00	0.007	8.36	0.004
Manual material handling	4.76	1.24–18.20	0.023	5.89	0.015
Awkward occupational postures	0.54	0.29–1.01	0.056	4.25	0.039
Psychosocial risk factors	1.51	1.02–2.24	0.041	4.52	0.033
Spondylolisthesis					
Age	1.09	1.01–1.17	0.019	6.45	0.011
Gender	0.05	0.01–0.43	0.006	11.53	< 0.001
Practice of sport	15.82	1.37–183.02	0.027	5.69	0.017
Lifetime working exposure	0.98	0.97–0.99	< 0.001	17.85	< 0.001
Self-reported heavy workload	7.19	1.50–34.48	0.014	7.49	0.006
Prolonged occupational sitting	0.35	0.13–0.95	0.039	6.46	0.011
Disc narrowing					
Professional vehicle driving	0.22	0.05–0.92	0.038	3.91	0.048
Disc herniation					
Age	0.94	0.90–0.99	0.011	7.22	0.007
Gender	3.83	1.12–13.08	0.032	5.09	0.024
BMI	0.83	0.72–0.97	0.017	6.60	0.010
Awkward occupational postures	0.64	0.40–1.03	0.064	3.60	0.058

Table 6 Determinants of morphologic outcomes in multivariate backward linear regression analysis

Explanatory variable	c	95% CI	P	Total R^2 (%)	R^2 Change (%)
Morphologic outcomes					
SDS score					
Age	0.12	0.05–0.18	0.001	6	6
Prolonged occupational standing	0.80	0.22–1.38	0.007	12	6
Lifetime workload exposure	−0.00034	−0.00007 to 0.000004	0.078	17	5
Number of degenerated discs					
Age	0.03	0.01–0.04	0.012	3	3
Prolonged occupational standing	0.21	0.04–0.39	0.017	8	5
Psychosocial risk factors	−0.17	−0.34 to 0.001	0.051	10	2
Family predisposition	0.50	−0.041 to 1.04	0.071	18	8
Severity of disc narrowing[a]					
Age	0.01	0.01–0.02	< 0.001	14	14
Family predisposition	0.19	0.01–0.38	0.044	17	3
Job workload category	0.06	-0.01 to 0.12	0.087	21	4
Number of herniated levels					
Gender	0.73	0.21–1.25	0.007	6	6
BMI	−0.08	−0.14 to −0.01	0.020	10	4
Number of stenotic levels					
Age	0.03	0.01–0.04	0.001	7	7
Job workload category	0.48	0.19–0.77	0.002	12	5
Psychosocial risk factors	0.16	0.03–0.29	0.019	13	1
Awkward occupational postures	−0.30	−0.56 to −0.04	0.026	16	3
Lifetime workload exposure	−0.00001	−0.00002 to −0.000001	0.028	20	4
Self-reported heavy workload	0.48	−0.06 to 1.03	0.082	23	3

[a]Subjects with disc narrowing ($n = 98$) were selected

activities and awkward posture, was used to further categorize the jobs of these participants. Psychosocial workplace factors were also analyzed on the basis of previously reported associations with low back disorders [22, 23]. Likewise, strictly defined quantitative data were used to assess the severity of degenerative changes in the lumbar spine in subjects who reported occupational risk. We also studied stenosis and spondylolisthesis, whose association with professional exposure had not been investigated to date.

In previous studies [4, 24, 33, 35], physical occupational risk factors have been reported to be responsible for the development of LBP. In our study the degree of disability, closely related to the chronicity of symptoms, was directly influenced by the heaviness of workload (higher job category). Our findings confirmed the importance of frequency of load handling, which has been emphasized in other studies [16, 24, 35]. Disability was also in inverse association with smoking at the multivariate analysis, but an artifact arising from either selection or confounding factors could be hypothesized for this negative association. Indeed, this habit has been associated with chronic LBP and disability in most recent studies [17, 18, 38].

Unlike clinical relationships, only sparse data are available on the morphological changes secondary to occupational exposure, and most studies have focused exclusively on the lumbar disc degeneration to the exclusion of other damage [3, 32]. An unbiased analysis of the occupational determinants of these changes is complicated by any concurrent age-dependent lumbar spine degeneration. Indeed, the significant and direct influence of aging on lumbar disk degeneration, end plate defects, osteophytosis of the vertebral body, and facet joint arthritis has been reported in one anatomic study [45]. Consistent with these findings, we detected a direct association of increasing age with the global amount of degenerative changes, the severity of intervertebral disc height loss, number of narrowed discs, stenosis, and spondylolisthesis. Conversely, disc herniation had a slight but significant inverse association. Apart from age, in our study several physical occupational determinants were significantly associated to the morphologic changes. In keeping with the conclusion of other authors [44], these occupational determinants explained little in the variability in outcomes. In detail, although no exposures influencing intervertebral disc narrowing were identified, prolonged occupational standing postures were associated with the involvement of more discs and a trend toward a direct association between increasing job workload and severity of disc height loss was observed as well. Detrimental influence of a heavy workload on lumbar disc degeneration has been previously reported [32, 33, 41], but a prospective MRI study failed to detect any association between occupational exposure and development of disc degeneration [13]. Our results are in keeping with this latter study. Indeed, both studies indicate that physical occupational risk factors have no significant effect on the development of disc narrowing. In the current study these factors were instead associated with increased number of involved discs and tendency toward more severe disc height loss in subjects in whom disc degeneration was already present. In other words, in people with a possibly innate tendency to develop degeneration, the heavier the workload the greater the severity of disc degeneration. Previous studies also provided evidence that a family predisposition has significant implication in lumbar degenerative disc disease [36, 39]. According to the results of one anatomical study [45], the increased severity of disc abnormalities among manual workers is probably secondary to mechanical overloading that eventually leads to the structural damage.

After adjusting for confounding variables, self-perception of a heavy workload and work requiring manual materials-handling were factors predictive of a condition of spondylolisthesis and lumbar spinal stenosis, respectively. To the best of the authors' knowledge, the relationship between physical occupational risk factors and spinal stenosis or spondylolisthesis has not yet been reported, even though short radiographic anteroposterior foraminal diameters have been noted among men doing manual work [43]. In the present study, awkward occupational postures, prolonged occupational sitting, and lifetime work exposure were inversely associated to several morphologic outcomes. As in cross-sectional studies it is impossible to assess the principle of causality, the morphologic changes in the lumbar spine are likely to be cause rather then consequence in these inverse relationships. Nevertheless, poor postures at work also entered in the composition of the job category scale and this parameter was directly associated with the degree of disability in our study. Mutual relationships between awkward postures and back pain have been previously reported [8, 9, 24], but this exposure per se cannot easily cause pathologic changes in the spinal structures [40]. Therefore, this finding may partly reflect the ability of awkward occupational postures to provoke symptoms originating from soft tissue without spinal derangements [40]. In our study inverse association between BMI and disc herniation was also found. Complex relationships between disc herniation and anthropometric features could explain this inverse relationship. Indeed, patients with lumbar disc herniation often have asymmetry and sagittalization of facet joints, and these alterations are more evident in the taller patients [29] with low BMI.

We did not find more frequent or severe changes in the lumbar spine in subjects driving professional vehicles and in fact driving was associated with less disc narrowing. Earlier studies [20, 30] have cited occupational driving as a risk factor for a herniated lumbar intervertebral disc. This adverse effect has been attributed to whole-body vibration with secondary mechanical overload of the lumbar intervertebral disc leading to early and accelerated degeneration [28]. Although this finding in the current study must be interpreted cautiously because of the small number of subjects exposed to occupational driving, our results are in keeping with the results of other authors. Indeed, a recent case-control study failed to find significant influence of occupational driving on lumbar disc degeneration [3] and less symmetric disc degeneration in cadaveric material of professional drivers was found in another study [45].

In our study, duration and discogenic characteristics of the pain were directly related to psychosocial occupational risk factors. It is unclear whether the psychosocial occupational discomfort at work plays a role as a pathogenic factor in these correlations, or whether it is instead a consequence [5], even though a systematic review of prospective studies on this topic [23] has stressed the effect of low social support and low job satisfaction at work on the occurrence of back pain. In other studies [10, 16] psychosocial occupational factors have been proven to be associated with the development of chronic occupational complaints. Chronicity has been precisely represented in terms of long-lasting pain, sick leave, or equivalent disability [18]. In our study group, stenosis and number of stenotic levels but not disc narrowing were in direct relationship with psychosocial occupational factors and these associations are likely to be related to chronicity of the symptoms. Nevertheless, also people with degenerative disc disease often have chronic pain. The lack of correlation between disc degeneration and psychosocial discomfort could lie on different characteristics of patients with stenosis and degenerative disc disease. Indeed, Amundsen et al. [1] noted that their patients with symptomatic lumbar spinal stenosis were 10–15 years older, had longer duration of symptoms, and complained of more painful standing and walking than patients with disc problems. In the current study aging also was associated to longer duration of pain and it could account for additional psychosocial discomfort in the participants.

As controversy still remains about the relationship between degeneration of the lumbar spine and pain [33], we also evaluated the clinical meaning of degenerative changes under examination. Weak direct association between global amount of degeneration in the lumbar spine and disability score was found, but the influence of female gender accounted for most of the variability in this outcome. The chronicity of complaints could explain these relationships, both for the influence of female sex, as middle aged women are particularly prone to develop chronic pain syndromes for sociocultural and biologic factors [25], and for the detrimental effect of degenerative changes. Indeed, we found direct influence of SDS score and severity of disc narrowing on the duration of pain. The hypothesis is further strengthened by the results of another study [46], in which association between lifetime number of pain episodes and severity of disc height narrowing was detected. The severity of disc height reduction was also the only explanatory variable associated with a condition of discogenic pain. This finding confirms the ability of the questionnaire for discogenic LBP to identify patients with disc abnormalities [39].

We acknowledge several methodological flaws in the present study. One drawback is its cross-sectional nature, which prevents us from inferring causality. Indeed, exposure and outcome are assessed simultaneously in studies with such a design and this issue could have biased the evaluation of some physical and psychosocial exposures as occupational risk factors in the present analysis. Moreover, complexity of the assessment and costs of MRI examinations limited the number of participants enrolled and the relatively small sample size might be a greater problem for the effects not found than for those found. Recall bias is another source of potential error, as it may affect detailed assessment of LBP [33]. However, there is a growing body of evidence supporting the validity of patient recall for LBP even after 10-year follow-up [11, 48], particularly when no treatment effects are under examination. To minimize the bias, we asked our patients to recall episodes of their usual LBP, as the usual pain is highly correlated with the actual pain and therefore it can be recalled more easily [27]. Last limitation of the present study is the high portion of unexplained variability in the outcomes, that is attributable to problems in measuring occupational exposures and outcomes, as well as to complexity of the relationships of individual and occupational risk factors with LBP and lumbar spine degeneration. Nevertheless, these drawbacks did not obscure the clear association of prior occupational conditions with the degree of degeneration in the lumbar spine. On the contrary, our study has two main methodological strengths: (1) the use of thorough imaging assessment with morphologic changes in the lumbar spine evaluated by unbiased reviewers using numerical scales and physical (dural sac cross-sectional area) measurements and (2) the careful qualitative and quantitative evaluation of occupational exposures. These explanatory and outcome variables could be used fruitfully in a longitudinal study.

Conclusion

Although physical occupational exposure was not associated with the presence of lumbar disc degeneration and narrowing per se, a higher degree of such an exposure was directly associated with a higher degree of degeneration. Moreover, some abnormalities not previously investigated, e.g., spondylolistesis and stenosis were also directly related to heavy workload and the manual handling of materials, and detrimental effect of a heavy workload on the degree of disability was detected. After adjusting for individual factors and family predisposition, the single occupational determinants explained less than 10% in the variability of morphological and clinical outcomes. Whether these correlations can fully explain the occurrence of LBP and disability in workers doing heavy manual labor is unclear, but these quantitative results further buttress the case for the detrimental effect of heavy physical workload on the severity of degenerative changes in the lumbar spine. As in this cross-sectional study, we also found significant influence of the total amount of degeneration in the lumbar spine on pain duration and degree of disability, additional caution should be exercised whenever subjects with well-established degenerative changes engage in physically arduous work.

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