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Exposure assessment of risk factors for disorders of the back in occupational epidemiology

by Alex Burdorf, MSc¹

BURDORF A. Exposure assessment of risk factors for disorders of the back in occupational epidemiology. *Scand J Work Environ Health* 1992;18:1—9. This review describes methods for assessing exposure to postural load of the back in occupational epidemiologic studies. Eighty-one original articles were selected that presented information on the prevalence of back disorders in occupational groups. In 47 (58%) of these studies no data on exposure to risk factors were given. In the remaining 34 studies (42%) exposure assessment was performed by questionnaire (33%), observation (9%), and direct measurement (5%). Measures of exposure were predominantly presented at the nominal and ordinal levels. It is argued that in most epidemiologic studies on disorders of the back in occupational groups the quality of exposure data is poor. Quantitative measurement methods need to be developed for application in occupational epidemiology.

Key terms: measurement, postural load, questionnaire, reliability, review.

Disorders of the back have been recognized as one of the most important occupational health problems. In many occupational populations disorders of the back, especially low-back pain, are the main reason for sick leave and for permanent disability (1). However, for the vast majority of workers with symptoms of the back, the underlying cause of these symptoms is unknown, as the role of many contributing factors in the etiology of disorders of the back is generally unclear (2). In work environments mechanical load on the spine is considered to be of causative importance to disorders of the back (3—5).

In the process of unraveling the multifactorial etiology of disorders of the back, epidemiologic studies are needed to investigate possible associations between exposure to specific work conditions and the development of disorders of the back. Considerable effort has been given to establishing standardized classifications and diagnoses of disorders of the back, for example, for low-back pain (6, 7) and low-back injuries (8). Less attention has been paid to characterizing biologically relevant measures of exposure in epidemiologic studies on disorders of the back. In many of these studies the measurement of exposure has been restricted to job titles or job categorization (9, 10). It can be expected that a proxy such as job title has a limited correlation with the actual exposure (11). Thus the assignment of subjects to exposure categories in a study based upon job titles is easily subject to exposure misclassification. As a consequence, real associations between exposure

to risk factors and specific disorders of the back can remain undetected and the strength of the relationships can be underestimated (12).

Inappropriate modes of measurement may partly explain the lack of knowledge on risk factors for occupational disorders of the back. Therefore, I have reviewed the literature to gain insight into the measurement methods used in occupational epidemiology to identify workplace factors which can increase the mechanical load on the spine. In accordance with Andersson (13) six primary vocational risk factors can be distinguished. They are heavy physical work, static work posture, frequent bending and twisting, lifting and forceful movements, repetitive work, and vibration. Although physiological and psychosocial factors and also safety aspects (14—16) can be of causative importance to the development of disorders of the back, I have restricted this review to occupational risk factors of chronic strain over long periods of time.

The purpose of the present article is twofold, (i) to evaluate methods employed to assess exposure to specific risk factors for disorders of the back in occupational epidemiology and (ii) to evaluate measures and procedures to quantify exposure assessments of these risk factors.

Selection of references

An extensive search of the available literature was made for studies published in 1981—1990. I used data bases such as Medline to select relevant articles. Ten scientific journals which regularly pay attention to the epidemiology of musculoskeletal disorders were manually searched. The primary key words used were back, backache, work, and risk factor. The secondary key words were back pain, back disorders, musculoskele-

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tal system, musculoskeletal complaints, postural load, and occupation. The initial selection consisted of 104 articles in which any attempt had been made to describe the prevalence or incidence of disorders of the back in specific occupational groups or to relate the occurrence of back disorders to specific work conditions. Reports on occupational risk factors associated with accidents causing back injuries were not taken into account. Studies focusing on individual risk factors (eg, psychological, social, and anthropometric factors) were not examined. Neither were articles describing risk factors of back disorders in populations without clear reference to occupations or work conditions.

Each of the 104 articles selected was thoroughly checked according to a scheme of criteria for exclusion so that I could select studies pertinent to the subject of the review (table 1). The first reason for exclusion was that only original studies were to be taken into account. Fifteen references were excluded because they only reviewed studies on back disorders without paying attention to the quantification of exposure to risk factors (2, 13, 17–29). Another eight papers were not selected since they simply reported in a slightly different way on a previously published study (30–37).

The second criterion applied was that the articles should contain more or less quantitative data on exposure to one or more risk factors. Among the 81 remaining references, only 34 studies were eligible for this review since they provided some numerical information on exposure variables, measured at least at the ordinal level. Thirty-eight publications were excluded because they only mentioned occupations or job titles and did not contain any meaningful exposure data (38–75). An additional nine studies were not retrieved since measures of exposure were restricted to information on presence or absence of certain risk factors (5, 76–83).

The remaining 34 articles were used to evaluate the methods of measurement of exposure to specific work-

place factors (84–120). Two articles of the same research group were treated as one publication since the first article (120) presented the exposure data for the populations under study and the second (106) described the prevalence of disorders of the back in both occupational populations. The same procedure was applied to studies of postural load and back pain among nurses (95–96) and postural load and back pain among fishermen (115–116).

Methods of measurement

Thirty-four original works with useful measures of exposure were selected. The methods of measurement used in these studies can be divided into the following three broad groups: (i) questionnaires ($N = 27$), (ii) observational methods ($N = 7$), and (iii) direct measurement techniques ($N = 6$). The application of questionnaires can be split into 19 studies in which the questionnaire was self-administered and eight studies in which workers were interviewed by means of a structured questionnaire.

Table 2 shows the great variety of measures used in the questionnaire surveys to quantify exposure at the workplace to specific risk factors for disorders of the back. Forty-six measures of exposure were found, mainly focused on lifting and forceful movements (17 measures in 17 studies) and static work posture (9 measures in 13 studies). The responses to the questionnaires can be classified according to the following three basic types: (i) nine yes/no responses used to ascertain the presence or absence of specific characteristics such as static work postures and lifting activities, (ii) 22 responses assessing specific characteristics of exposure on a scale ranging from three to five, such as physical work load and frequency of lifting activities, and (iii) 15 responses concerning measurable attributes on at least an interval scale, such as the number of hours sitting per shift and the average weight per lift.

The majority of the variables were measured at either the nominal (dichotomous) or ordinal level. Only 15 variables (33%) presented not only an ordering of separate categories, but also a meaningful measure of the distance between different categories.

Heavy physical work was measured by a questionnaire in 10 studies. In three papers subjects were asked to evaluate their work load by rating physical demands on a three- or five-item scale and thereby discriminate between subjective categories like "heavy physical work" and "light physical work" (93, 97, 112). In three more publications job titles or trade groups were used to classify subjects according to physical work (85, 103, 114). In two studies of the same research group the assessment of physical work load was based on the distribution of hours per day spent lifting, bending or rotating, standing, walking, and sitting (118–119). In a survey among school lunch workers

Table 1. Selection of epidemiologic studies which present measures of exposure to risk factors for disorders of the back in occupational situations.

	Included studies		Excluded studies	
	N	%	N	%
Initial examination	104	100	·	·
Selection criterion 1				
Review	·	·	15	14
Secondary analysis	·	·	8	8
Original works	81	78	·	·
Selection criterion 2				
Occupation or job title	·	·	38	37
Measures of exposure at dichotomous level	·	·	9	9
Original works with useful measures of exposure	34	33	·	·

an interesting proxy of work load was that of the total number of lunches prepared during a normal shift (105).

The importance of static work postures has been recognized by 13 investigators. The nine measures used mainly concentrate on duration of sitting per shift and prolonged strenuous postures. None of the studies presented a definition of strenuousness of specific postures in the questionnaire.

Frequent bending and twisting of the trunk was evaluated in 12 studies in which seven different measures were used. These measures included both the duration and frequency of this risk factor. A clear description of a bent and twisted posture of the trunk was not provided in any of the 12 publications.

Lifting and associated activities were evaluated as a possible risk factor for disorders of the back in 17 surveys. The characterization of exposure differed very much. In some questionnaires measurement was restricted to nonspecified categories like "sometimes" and "occasionally" (109), whereas in other investiga-

tions the category "sometimes" was exactly defined as lifting a load of more than 5 kg regularly but less than 10 times per hour (112–113). The variables for interval scales concentrated on the frequency of lifting loads (four measures), the duration of lifting activities (one measure), and the average weight of the load (one measure).

The relation of repetitive work and whole-body vibration to disorders of the back did not receive much attention. These risk factors were only taken into account in seven investigations.

Although the parameters of exposure were collected at the individual level in all of the questionnaire surveys, most of the studies used this information to assign the respondents to a limited number of exposure groups. Few studies applied multivariate statistical techniques to investigate relationships between exposure data at the individual level and their effects on the back (90, 95, 111, 119). The questionnaire approach was predominantly used in cross-sectional studies to assess exposure during current work condi-

Table 2. Variables used in 27 questionnaire surveys to measure exposure to risk factors for disorders of the back in occupational groups.

Occupational risk factor	Dichotomous variable ^a (yes/no)	Ordinal variable ^a (3 grades or more)	Interval variable ^a
Heavy physical work	Perspiration (109)	Worker's assessment 3 grades (93) 4 grades (112) 5 grades (97) Author's assignment By job title 3 grades (85, 103, 114) By other risk factors 3 grades (118–119)	Number of lunches prepared/shift (105)
Static work posture	Feet flat on floor (90) Maintaining uncomfortable posture (91)	Maintaining fixed posture 3 grades (113, 117) Hours of sitting per shift 3 grades (113, 117) 4 grades (112) Awkward postures 4 grades (89)	Hours of sitting/shift (84, 87, 88, 92, 110) Hours of standing/shift (84, 87, 88, 96, 117) Hours/shift with constrained posture (92, 98)
Frequent bending and twisting	Bending more than 10 times/h (91)	Twisted or bent posture 3 grades (113, 117) 4 grades (107) 5 grades (104)	Hours of bent posture/shift (84, 90, 100) Number of bends/h (90) Hours of twisted or bent posture/shift (87, 88, 118, 119)
Lifting and forceful movements	Lifting weights of more than 15 kg (91) Lifting patients more than 5 times/shift (91) Pushing beds more than 10 min/shift (91)	Frequency of lifting 3 grades (93, 112, 113, 117) 5 grades (109) Average weight per lift 3 grades (100) 4 grades (93) Average weight of load carried 3 grades (96, 100) Frequency of patient lifting 4 grades (118, 119) 5 grades (111) Frequency of forceful movements 3 grades (117)	Number of lifts/shift (84, 90, 96, 100) Average weight/lift (90) Hours of lifting/shift (87, 88, 92, 118, 119) Number of patients lifting/shift (96, 102) Number of pulls/shift (90, 96) Number of loads carried/shift (96, 100)
Repetitive movements	Monotonous and/or repetitive movement (109)	High repetition 4 grades (89)	Number of repetitive actions/min (98)
Whole-body vibration	Vibration (92, 109)	Annual amount of driving in kilometers 3 grades (107)	Hours of driving/week (90, 105)

^a Numerals in parentheses represent reference numbers.

tions. This actual exposure was regarded as a suitable proxy for retrospective exposure assessment. In one study the workers' ratings of physical work load in the base-line examination were used to investigate the influence of work load on the incidence of sciatica during an 11-year follow-up (97). In none of the 27 studies with questionnaires were repeated measurements conducted.

Observational methods and direct measurement techniques were applied in 11 studies. In three, observations were made at regular intervals by observers (96, 108, 120). In four, the acquisition and analysis of data on trunk posture was simplified with the use of video systems (89, 98, 101, 116). The methods of measurement and associated measures of exposure are presented in table 3. Twenty-six different measures of exposure were used, of which 14 variables (54%) were related to bending and twisting of the trunk. The observed motions of the trunk were bending forward (flexion), bending sideways (lateral flexion), and twisting (rotation). Correspondence with respect to the

classification of nonneutral trunk postures was low, although a difference of more than 20 degrees from a straight, neutral position was regarded as significant by several authors (101, 108, 116).

The presence of lifting activities and forceful movements was quantified differently in five studies. In one, a method of the United States National Institute for Occupational Safety and Health was used to evaluate manual lifting tasks (98). Exposure to whole-body vibration was directly measured in three studies of the same research group (86–88), according to the requirements of an international standard (ISO 2631) (121).

Observational methods and direct measurement techniques were applied in 10 cross-sectional studies (87–89, 94, 96, 98, 101, 108, 116, 120) and one retrospective follow-up study (86). In the latter, measurements of exposure to whole-body vibration were available from several periods which allowed the researchers to describe historical developments in exposure (86). The 10 cross-sectional studies focused on current exposure to risk factors. The common ap-

Table 3. Variables used in seven observational techniques and four direct measurement methods to measure exposure to risk factors for disorders of the back in occupational groups. (NIOSH = National Institute for Occupational Safety and Health)

Occupational risk	Variable in interval scale ^a
Heavy physical work	..
Static work posture	
Observation method	Number of static postures (at least 30s during patient handling)/shift (96) Percentage of worktime without movement (120) Number of postural changes/min (101)
Electromyography	Static load (N) of right lumbar erector (94)
Frequent bending and twisting	
Observation method	Percentage of static actions with trunk in asymmetric position (96, 98) Percentage of worktime with bent trunk Forward ($20^\circ < \alpha < 45^\circ$) (101) Forward ($\alpha > 45^\circ$) (101) Forward ($15^\circ < \alpha < 90^\circ$) (120) Forward ($\alpha > 90^\circ$) (120) Forward ($\alpha > 20^\circ$) (116) Forward ($\alpha > 45^\circ$) (108) Side ($\alpha > 20^\circ$) (101) Side ($\alpha > 30^\circ$) (116) Percentage of worktime with trunk Rotated (120) Rotated ($\alpha > 20^\circ$) (101, 108) Rotated ($\alpha > 30^\circ$) (116)
Direct measurement method	Flexion of the back Mean angle (89) Angular velocity (89)
Lifting and forceful movements	
Observation method	Number of patient handling/shift (96) Number of activities/shift involved lifting, pushing, or otherwise manipulating objects > 60 lb (27 kg) (96) Number of lifts/shift (weight of the load 5–20 kg, > 20 kg) (120) Number of handled weight/force or pulls (< 10 kg, 10–20 kg, > 20 kg) (116) Percentage of worktime Lifting (108) Pulling and pushing (108)
Direct measurement by NIOSH method	Weight, frequency of lifts, vertical location, and vertical travel distance (98)
Repetitive movements	..
Whole-body vibration	
Direct measurement method	Frequency-weighted root-mean-square acceleration (m/s^2) (86–88)

^a Numerals in parentheses represent reference numbers.

proach was based upon characterizing measures of exposure within distinguished occupational title groups. In two studies observations of frequent bending and twisting of the trunk were conducted for each subject (89, 101). In one study among helicopter pilots measurement of vibration levels of the current helicopters provided accurate estimates since the design of the helicopters had changed little over the last decade. The total cumulative vibration dose of each pilot could be calculated since their hours of flight were registered in a personal flight log (87). In contrast, the other studies had to rely on length of employment as an estimate of duration of exposure.

Discussion

In the past 10 years numerous reports have been published on the frequency of the occurrence of disorders of the back in different occupational populations under different work conditions. In this literature review 104 publications were examined, of which 81 (78%) were considered to be original work. It was surprising to find that 38 studies (37%) only focused on incidence, prevalence, and/or severity of back disorders in occupational groups without presenting any information on exposure to risk factors in these occupations. In nine more studies a crude classification into presence or absence of a specific risk factor had been used to investigate the influence of this risk factor on the occurrence of disorders of the back. Only in 34 of 81 (42%) original studies had an attempt been made to characterize exposure to risk factors at the workplace in a (semi) quantitative way.

The (self-administered) questionnaire technique was used the most frequently to collect information on exposure to risk factors in the workplace. Questions about work conditions were phrased in such a way that the answers were predominantly scaled at a nominal or ordinal level. Moreover, most questions consisted of qualitative descriptions, lacking a clear definition of categories of exposure. Such characterization of exposure will substantially limit the accuracy and preciseness of measures of exposure (122).

Since the questionnaire surveys derived measures of exposure from subjective responses, the validity of such measures must be considered before they can be regarded as unbiased estimators of true exposure to risk factors. However, the number of publications which addressed the issue of precision and validity was limited (87, 97, 100). Heliövaara (97) argued that the validity of the classification of self-assessed physical work load used in her study was questionable because no fixed criteria for strenuousness were given in the questionnaire. Another author mentioned that, despite the inevitable lack of precision of reported lifting and carrying activities, differences in exposure to this risk factor among workers could be ascertained (100). Two publications mentioned the application of a validated

questionnaire (109, 118) but further details were not given.

The restricted attention to random and systematic error in the measurement of exposure to postural load in the questionnaire surveys is remarkable because several studies have cast doubt on the determination of exposure to risk factors through questionnaire assessment (9, 123–125). Comparisons of questionnaire assessments with observational data have shown that reports on the time spent in specific activities like walking, standing, and kneeling are not very reliable (123, 124). Two studies have reported that the agreement between self-administered questionnaires by employees and direct observation by investigators was poor for bending and twisting of the trunk (124, 125). Hagberg and his co-authors found that questionnaire information and observational data on lifting activities were consistent for only 10% of the workers studied in regard to both the weight and frequency of the material handled (9). In a study on steel workers complementary results have been reported (124).

Observational techniques were applied in seven studies. The basis of such techniques is to show how a specific body segment derives from a given standard position and to calculate total postural load over work-time. Three research projects used a "pencil-and-paper" technique that required observers to register work postures and movements during a specified period at the workplace (96, 108, 120). Each publication made reference to training procedures of observers to ascertain repeatable results and to minimize inter-observer variability. Four studies applied a video-computerized technique for recording postures and movements (89, 98, 101, 116). The continuous video recording of selected tasks enabled them to perform a real-time analysis. The reliability of exposure data can be improved in this manner since the videotape can be reviewed several times by different observers in the laboratory. These computerized systems essentially provided the same measures of exposure for postural activity as observational techniques based upon observers at the workplace.

Application of observational methods will certainly increase the quality of exposure assessment. Several methods for systematically evaluating postures and movements during work have been described (126–131). Observational techniques are extensively being used in ergonomic studies to identify particularly strenuous tasks and awkward postures and to evaluate workplace improvements. It is apparent from this literature review that such observational techniques have hardly been employed in occupational epidemiology. The same conclusion can be drawn with regard to direct measurement methods, although some promising techniques for the continuous measurement of trunk movement during work have been developed (132, 133).

In epidemiologic studies on disorders of the back valid quantification of exposure to risk factors is dif-

ficult for various reasons. Exposure characterization has to take into account relevant strenuous postures and movements, their frequency and duration within and between shifts, and intra- and interindividual variability during work activities. Therefore, the application of observational methods or direct measurement techniques implicates assessment of exposure of many workers for several days. This is certainly a time-consuming, labor intensive and expensive activity (101), and therefore the applicability of these methods in (large) epidemiologic studies is limited. Thus feasibility considerations may well explain the common preference for (self-administered) questionnaires as a tool to assess exposure to risk factors for back disorders at the workplace.

Whenever objective measurement of exposure is not possible in an epidemiologic study, the validity of the questionnaire developed should be studied prior to the study, for example, by comparing the questionnaire with objective, direct measurement techniques. Special attention should be given to between-group and within-group variances to investigate whether it is possible to distinguish homogeneous exposure groups in the population under study. If the within-group variance is large in comparison with the between-group variance, the ranking of exposure groups is severely hampered. Retrospective epidemiologic studies advocate the use of questionnaires. Again there is a clear need for validation of the questionnaire applied. Attention should not only be given to exposure variability at the group level, but also to between-worker and within-worker variance. Repeated measurements in time may be useful to distinguish between a worker's personal distribution of day-to-day exposures and a change in exposure over time. If the within-worker variance is large in comparison with the between-worker variance, the application of questionnaires for estimating past exposures is limited. This exposure assessment strategy may also be an important feature of a prospective measurement strategy.

Concluding remarks

Epidemiologic research is needed to evaluate the possible associations between workplace exposures and adverse human health outcomes such as disorders of the back. This extensive literature review revealed that an important drawback of many epidemiologic studies on disorders of the back is the poor quality of available exposure data. In 58% of the original studies examined ($N=47$), no information on exposure to specific risk factors was given. In the remaining 42% (ie, 34 studies) exposure data were collected with a questionnaire in 27 studies. The validity of questionnaires applied was evaluated in only a few studies. Measures of exposure were predominantly presented on a nominal or ordinal scale. This procedure limits the precision of measures of exposure and, consequently, in-

creases the misclassification of exposure. Preferable measurement of exposure, based upon quantitative measures of exposure in observational methods or direct measurement techniques, has only been applied in 11 original studies (14%).

The characterization of exposure to workplace factors is frequently made difficult by the simultaneous action of several factors whose interrelationships and relative importance are not well understood (134). Although a major problem is the fact that still little is known about which exposure variables are risk factors for occupational disorders of the back, there is a clear need for the development of better objective measures of exposure to occupational risk factors (9, 10, 134). Valid quantitative measures of exposure are necessary in prospective epidemiologic studies to identify the role of various risk factors in the development of disorders of the back and, consequently, to establish dose-response and time-response relationships. Valid questionnaires for exposure assessment are needed in retrospective epidemiologic studies.

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