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ORIGINAL ARTICLE

# Daily spinal mechanical loading as a risk factor for acute non-specific low back pain: a case–control study using the 24-Hour Schedule

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**Abstract** A case–control study was conducted to assess the daily loading of the spine as a risk factor for acute non-specific low back pain (acute LBP). Acute LBP is a benign, self-limiting disease, with a recovery rate of 80–90% within 6 weeks irrespective of the treatment type. Unfortunately, recurrence rates are high. Therefore, prevention of acute LBP could be beneficial. The 24-Hour Schedule (24HS) is a questionnaire developed to quantify physical spinal loading, which is regarded as a potential and modifiable risk factor for acute and recurrent low back pain. A total of 100 cases with acute LBP and 100 controls from a primary care setting were included. Cases and controls completed questionnaires regarding acute LBP status and potential risk factors. Trained examiners blinded to subjects' disease status (acute LBP or not) assessed spinal loading using the 24HS. The mean difference of 24HS sum-scores between groups was statistically significant ($P < 0.0001$). After multivariate regression analysis, previous episode(s), the 24HS and the Nottingham Health Profile were associated with the presence of acute LBP. High 24HS scores, indicating longer and more intensive spinal loading in flexed position, are strongly associated with acute LBP.

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**Keywords** Case–control study · Low back pain · Risk factor · Mechanical load · 24-Hour Schedule

## Introduction

In the Netherlands, 15% of the total working-age population currently claim disability insurance [24]. Each year, low back pain accounts for 13% of all new cases [28]. Despite this burden for patient and society, a clear aetiology of low back pain is unknown. About 85% of the cases with low back pain are labelled as non-specific, i.e. not attributed to recognisable pathology [11]. Acute non-specific low back pain (acute LBP) is considered a benign self-limiting disease, with a recovery rate of 80–90% within 6 weeks in the open population, irrespective of the type of management or treatment [27]. Nevertheless, recurrence rates are reported as high as 50% in the following 12 months [7]. Prevention might be beneficial in the management of acute LBP. For prevention, knowledge of the risk factors is essential, but in general these are poorly understood [5]. Nonetheless, there are indications that physical activities, i.e. manual material handling, bending, twisting (heavy load) and whole-body vibration, are possibly risk factors for acute LBP [13, 15, 19]. Quantification of mechanical load, posture and spinal load applied, could be useful to identify the physical risk factors. For this purpose, the 24-Hour Schedule (24HS) was developed [6]. The 24HS is a one-dimensional questionnaire measuring spinal mechanical load in the subject at issue. The 24HS has face and content validity, and the interobserver reliability was shown to be high [6].

The purpose of this study was to investigate the 24HS scores as potential independent risk factor for acute LBP.

## Methods

### Study population

Forty general practitioners in the city of The Hague, The Netherlands, referred patients diagnosed with acute (i.e. an episode lasting less than 6 weeks) non-specific low back pain (acute LBP) to one of the assessors in one of the four local research centres. Patients were eligible for inclusion if an assessor confirmed the 'diagnosis' (acute LBP) and the presence of exclusion criteria were excluded. Exclusion criteria were: insufficient understanding of the Dutch language, previous episode(s) of acute LBP in the past 12 months, low back pain after a recent trauma, pregnancy, spinal surgery and known pathology suspicious for/or specific low back pain. Definitions used in this study are in accordance with the Dutch Guideline for General Practitioners 'Low Back Pain' and internationally accepted [11].

For every case, a subject for the control group was recruited, having a pain-free and unlimited function of the back for a period of at least 12 months. The first *new* patient with any condition who entered a research centre for physical therapy (ergo after inclusion of a case) was in principle eligible as a control. Exclusion criteria were: insufficient understanding of the Dutch language, pregnancy, complaints of the spine, i.e. pain or stiffness in rest or during activities, and a previous assessment in this study.

For all subjects, participation in the study was strictly on a voluntary basis.

### Assessment

All 18 assessors were physiotherapists trained in using the 24HS. An assessor performed the inclusion procedure, in which all subjects signed informed consent and were coded to remain anonymous. Questionnaires focusing on subjects' history, demographical data and known risk factors (i.e. heavy load, whole-body vibration, gender, age, bodyweight [14], smoking habits, length [26] and previous episode(s) of low back pain—hereafter called previous episode(s) [8]) were completed. Scoring of previous episode(s), whole-body vibration, heavy load and smoking was dichotomised into present (subject indicated having experienced the risk factor) or not present (subject did not indicate having the risk factor). If relevant, the period (in years) between the last episode of low back pain and the assessment was registered: the *pain-free interval*. The generic health-related quality of life measure, Nottingham Health Profile (NHP)—Dutch version [10], was used for the measurement of psychosocial risk factors [20]. The scores of the six domains of the NHP I and II were summed. The presented score (range 0–87) is the mean across all items. The spinal pain intensity was measured with an 11-point Numeric Rating Scale (NRS) [16]. Subjects were asked to choose one of the available categories: 'sitting', 'standing', 'walking', 'variable', or 'heavy physical' to represent their most important physical activity during daily occupation or profession.

A second assessor, uninformed of subject's status (i.e. being a case or a control subject), exclusively performed the 24HS measurement. This assessor systematically asked the subjects to describe their daily activities. In each activity, the position of the back in the sagittal plane (i.e. flexed or extended), the load applied and the duration were listed chronologically on the standardised registration form (see Appendix). For 'load applied' three categories were available: (1) no load applied (e.g. lying), (2) loaded (e.g. sitting) and (3) loaded with movement (e.g. digging). After completing the registration, subject's flexed-posture score was first calculated. For each activity, the duration was multiplied by the weight of the category the activity was scored in and all obtained scores were added up. The weight of the categories, based on Nachemsons' findings [23], was set to 1:2:3 [6]. For example, an activity scored 5 h in the second category on the registration form becomes 10 h when recalculated to the first category. An activity scored 5 h in the third category will be recalculated to 15 h in the first category. The resulting figure represents the time the back was loaded in a flexed posture with a load of the first category. The parameter we called *Schedule hours* ranges from 0 to 72. Subsequently, this procedure was repeated for the extended posture (range 0–72). The sum-score was obtained by subtracting the total time of the extended postures from the total time of the flexed postures. The resulting figure gives insight into the dominant use (the training activity) of the back (range – 72 Schedule hours to + 72 Schedule hours). Negative sum-scores point to an overall spinal use in extended postures and positive sum-scores indicate an overall spinal use in flexed postures.

During the assessment, subjects were asked explicitly not to inform the assessor about their role in the study. Subsequently, for the cases, their first assessor explained the outcome of the assessment and summarised this in an information brochure named ‘About Your Back’. Controls received no additional information. The total time required for the assessment was 30 min.

In this study, the dependent variable was the presence of acute LBP. The independent variables were the 24HS sum-scores, and the following risk factors for acute LBP: gender, age, weight, length, smoking, whole-body vibration, heavy load, previous episode(s) and the NHP.

### Analysis

The odds ratio (OR) was used to express the association between the dependent and the independent variables. For the association between the dependent variable (acute LBP or not) and the mean 24HS sum-scores, an OR of 1.5 was considered clinically relevant. Power analysis indicated that (using an alpha of 0.05 and a power of 0.80) 200 participants (100 cases and 100 controls) would be sufficient to detect such difference with statistical significance.

After blinded, double data entry, all analyses were carried out using SPSS 11.0. First, frequencies of risk factors are presented with their mean and standard deviation (SD). In case of skewed distributions, median and interquartile range (IQR) were used. Next, groups were compared using the Independent Samples *T* Test or, in case of skewed distributions, the non-parametric Mann–Whitney *U* Test. A logistic regression analysis was used for calculating the associations between the presence of acute LBP and the independent variables. After a univariate regression analysis, a multivariate logistic regression model (backward Wald) was run on the independent variables that showed a relation to the presence of acute LBP. Threshold for entry of independent variables in the multivariate model was $P < 0.05$ and for removal $P > 0.1$ [4]. The Nagelkerke $R^2$ was used to assess the explained variance of the model.

The procedures followed were approved by the Medical Ethics Committee of the Erasmus Medical Centre (Rotterdam, The Netherlands), in accordance with the Research Code of the Academic Medical Centre (Amsterdam, The Netherlands).

## Results

From October 2003 to October 2004 a total of 100 cases and 100 controls were included. The characteristics of the study population are presented in Table 1.

The controls were recruited from patients who were newly referred for physical therapy. The majority ($n = 54$) of controls had a complaint in the lower limb, and 16 were referred with shoulder problems. More serious pathology occurred in eight controls (i.e. fracture in four, postoperative in three and both in one). No specified complaints occurred in 12, and missing values in 10 controls.

Two subjects in the case group indicated no pain during the assessment and in contrast, 28 scored NRS ≥ 8 of which two indicated the maximum pain score. Two cases and six controls did not fulfil the inclusion criteria completely. Four subjects (two cases and two controls) experienced low back pain in the previous 12 months and four controls reported minor low back pain (NRS = 1) during the assessment. Retrospectively, confronted with these incorrect included subjects we decided to analyse all included subjects.

For daily occupation or while-at-work, 57 cases (mean score 34.7 Schedule hours) and 56 controls (mean score 10.3 Schedule hours) were ‘sitting’. ‘Variable work’ occurred in 28 cases (mean score 32.1 Schedule hours) and 32 controls (mean score 12.0 Schedule hours), ‘heavy physical’ indicating daily heavy loading of the spine in 35 cases (mean score 36.4 Schedule hours) and 22 controls (mean score 14.3 Schedule hours). There was no statically significant association between the outcome, the presence of acute LBP and the categories representing subjects’ most significant physical activity during their daily occupation or profession. Also, there was no statistically significant difference in median years that controls and cases performed their daily activities preceding the moment of assessment; here the values from 11 controls and 12 cases were missing. Three cases indicated an unrestricted spinal function, while they were experiencing low back pain, of which one indicated NRS = 7.

### Assessed postures

Flexed postures were registered in all 200 assessments. The mean difference of 14.1 Schedule hours between cases and controls was statistically significant ($P < 0.0001$). No extended postures were measured in 9 controls and 88 cases. The difference between the groups was statistically significant ($P < 0.0001$).

### Sum-scores

In the case group, two negative sum-scores were assessed, while the other cases scored 14 Schedule hours or more. Twelve negative sum-scores were found in the control group, see Fig. 1. The mean difference in sum-scores (23.0 Schedule hours) between cases and controls was statistically significant ($P < 0.0001$).

**Table 1** Characteristics of the study population ($n$ = 200)

| Baseline characteristics | Case | Control |
|---|---|---|
| Male | 52/100 | 58/100 |
| Age (range, SD) | 40.7 (15–82, 13.5) | 39.8 (18–76, 13.5) |
| Weight (kg; range, SD) | 75.2 (45–115, 14.5) | 74.4 (47–108, 13.3) |
| Length (cm; range, SD) | 176.2 (152–200, 10.6) | 175.4 (154–200, 10.0) |
| Whole-body vibration | 8/100 | 5/100 |
| Heavy load | 35/100 | 22/100 |
| Smoking | 34/100 | 18/100 |
| Previous episode(s) of low back pain | 70/100 | 39/100 |
| Pain-free interval (median, range) | 2 (0.5–25) | 3 (0–30) |
| Pain NRS (median, range) | 6 (0–10) | 0 (0–1) |
| Pain radiating in one or both legs | 35/100 | 0/100 |
| NHP sum-score (mean, SD) | 2.88 (2.2) | 1.15 (1.6) |
| 24HS flexed postures (mean, SD) | 35.2 Schedule hours (SD 5.5) | 21.1 Schedule hours (SD 5.8) |
| 24HS extended postures (median, IQR) | 0 Schedule hours (0–0 Schedule hours) | 10 Schedule hours (4.5–14 Schedule hours) |
| 24HS sum-score (mean, SD) | 34.4 (8.2) | 11.4 (9.7) |

Risk factors for low back pain

First, a univariate regression analysis was performed including the ten potentially relevant independent variables: gender, age, weight, length, whole-body vibration, heavy loading, smoking, previous episode(s), NHP and 24HS sum-scores. Of these, the 24HS sum-scores, NHP, previous episode(s), heavy loading and smoking were univariate significantly related to the outcome, the presence of acute LBP. After a multivariate regression analysis, the 24HS sum-scores as well as the previous episode(s) and the NHP scores remained significantly associated with acute LBP. Table 2 presents the results of the univariate and multivariate analyses.

The OR for previous episode(s) is 5.55. The other predictors (NHP and 24HS) are continuous values. Consequently, the OR for acute LBP increases by a factor of 1.26 for every additional 24HS score and 2.40 for every additional NHP score. Therefore, the smallest association was for the NHP scores and acute LBP, and the strongest association for 24HS scores and acute LBP, as shown in Table 3.

The percentage of the total log likelihood for LBP explained by the significant independent variables (i.e. 24HS sum-scores, previous episode(s) and NHP) amounted 78.7% (Nagelkerke $R^2$).

A subgroup analysis was performed in the group of subjects with a previous episode of acute LBP evaluating the pain-free interval. Only in the univariate model was the influence of the pain-free interval significantly associated with acute LBP. However, this association was not statistically significant in the multivariate model (OR 0.95, 95% CI 0.85–1.07).

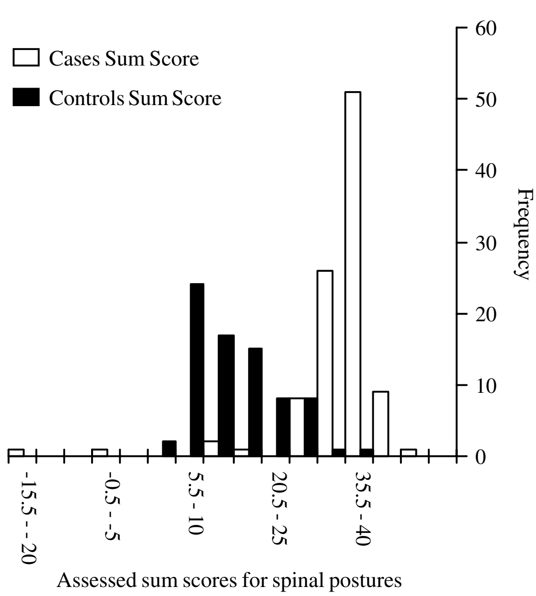


**Fig. 1** Assessed sum-scores for spinal postures

## Discussion

High 24HS scores were strongly associated with acute LBP in this study. The odds for having acute LBP is 1.26 to 1, and increases by this factor for every additional schedule hour. The few and mostly small extended scores of the cases could explain this high association. In a previous reliability study the difference between the flexed and extended scores was also substantial [6]. Although the study population differs, these findings are consistent with the results in the present study.

In view of the assessed association, we have to bear in mind the following limitations. Results of 'case–control studies' are likely to be overestimated [18]. Bias is expected using retrospective data for subjects' description of 'an average day'. The reproducibility of the 24HS was high [6]. Nevertheless, the accuracy of the assessor

**Table 2** Results of regression analysis

| Predictors | Exp B, univariate (95% CI) | Exp B, multivariate (95% CI) |
|---|---|---|
| Gender | 0.784 (0.45–1.37) | – |
| Age | 1.01 (0.96–1.03) | – |
| Weight | 1.00 (0.98–1.02) | – |
| Length | 1.01 (0.98–1.04) | – |
| Whole-body vibration | 1.65 (0.52–5.24) | – |
| Heavy loading | 1.91 (1.02–3.57) | 0.69 (0.09–5.3) |
| Smoking | 2.35 (1.21–4.53) | 3.08 (0.43–22.06) |
| Previous episodes | 3.65 (2.03–6.66) | 5.55 (1.72–17.87)* |
| Nottingham Health Profile | 1.60 (1.34–1.92) | 2.40 (1.33–4.30)* |
| 24HS sum-score | 1.25 (1.18–1.33) | 1.26 (1.14–1.38)* |

Predictors for acute LBP expressed in exponent B (OR) with their 95% confidence interval, in univariate and multivariate analysis

– = variable not taken into multivariate analysis ($P > 0.1$); * = variable statistically significant in multivariate analysis

will determine the results. A questionnaire was used to quantify the mechanical load of the back. The results might be different when using more quantitative measuring methods. Therefore, the obtained scores are considered a conscientious indication of the mechanical load. Hypothetically, serious pathology in the control group and severe acute LBP in the case group could possibly reveal an indication of the subject's disease status to assessors. Initially, we did not recognise that this could endanger blinding and possibly bias the results. For this reason, we did not collect any data indicating that the assessor was aware of the subjects' status (case or control). Theoretically, blinding could have been insufficient in 36/200 (18%) of the assessments. Nevertheless, the association between 24HS scores and the presence of acute LBP seems substantial. Of course, this finding needs replication in other studies and populations. If high 24HS scores are indeed associated with acute LBP, this may be a target for preventive measures [6]. Whether these measures (i.e. focusing on the reduction of flexed postures in patients) are effective or not needs to be investigated in controlled studies.

Psychosocial risk factors were measured with the generic health-related quality of life measure (NHP). To avoid bias, controls were recruited from patients with a variety of other complaints. Thus, the contrast between cases and controls was minimised in all aspects. The association between acute LBP and 24HS, NHP and other risk factors could be higher if more 'extreme groups' were included in this study.

**Table 3** Progress of the OR for acute LBP in successive 24HS and NHP scores

| Subjects' 24HS score (Schedule hours) | Related OR for LBP (95% CI) | Subjects' NHP score | Related OR for LBP (95% CI) |
|---|---|---|---|
| 1 | 1.3 (1.2–1.3) | 1 | 1.4 (1.0–1.9) |
| 10 | 9.1 (5.0–16.7) | 1.7[a] | 1.8 (1.1–3.0) |
| 23[a] | 161 (40–652) | 3 | 2.7 (1.1–6.7) |

[a]Mean difference

Previous episodes were associated with acute LBP, but a long pain-free interval is probably a protective factor for recurrences.

A flexed and an extended position will affect the musculoskeletal system of the lumbar spine in different ways [1, 2, 9]. From the physiological point of view, the musculoskeletal system of the spine weakens from overuse or disuse [25]. In our study population, cases indicated an intensive use of the back in a flexed position. It seems plausible that the musculoskeletal system of the back, in the flexed position, might constitute overuse, causing acute LBP. Then cases also indicated an absence of use in an extended position. Thus, disuse of the musculoskeletal system of the back involved in an extended position is also a plausible explanation for acute LBP. In the literature, several studies support this suggested relation between (sudden) lordotic activity and the occurrence of low back pain [3, 21, 22].

There was no statically significant association between the presence of acute LBP and the categories representing subjects' most important physical activity during their daily occupation or profession. As for 'sitting', Hartvigsen et al. [12] concluded that sitting-while-at-work is not associated with low back pain. Our findings are consistent with that conclusion. Sitting-while-at-work or daily occupation occurred in 57 cases (mean score 34.7 Schedule hours) and 56 controls (mean score 10.3 Schedule hours). Apparently, the controls modified their 24HS sum-score by common daily activities, e.g. through sleeping posture, sport, leisure time or a maintained lordotic posture of the lumbar spine during sitting. Consequently, sitting-while-at-work as potential risk factor for acute LBP cannot be regarded independently of other daily activities.

Considering the difference between cases and controls in 24HS sum-scores, the value of isolated physical risk factors could be limited due to the weight of common daily activities on spinal load, when identifying mechanical load as risk for low back pain. Therefore, we suggest involving all daily physical activities when exploring mechanical load as a risk factor in low back pain.

When present in other studies, the association between smoking and low back pain is expected to be weak and clearly apparent only in large study samples [17]. Not including smoking as a risk factor in the multivariate analysis is most likely due to the sample size.

The above-mentioned risk factors for acute LBP could also have value as prognostic factor for recurrent or chronic low back pain. This should, however, be evaluated in a further prognostic study.

### Generalisability

The cases were recruited from subjects consulting their general practitioner for acute LBP. Due to the inclusion criteria and definitions, as described in the Dutch Guideline for General Practitioners [11], the subjects represented a good reflection of the source population in primary care. To improve understanding in the risk factors for acute LBP, a 'first-time-ever' population could be ideal. We also considered patients with a pain-free and unlimited function of the back, for at least 1 year, eligible to enter the study. Subjects with recent exacerbations and/or chronic low back pain were excluded. In this manner, bias of the potential prognostic factors on the development of acute LBP was avoided. Finally, no matching was applied for the selection of cases and controls. Instead, logistic regression was used to assess the influence of potential risk factors on the presence of acute LBP.

## Conclusion

High 24HS scores, indicating increased daily loading of the spine in flexed position, was associated with the presence of acute LBP in this study. This finding warrants further study of its use identifying the physical risk factors for acute LBP, which might enable preventive strategies to be developed.

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## Appendix

Figure 2.

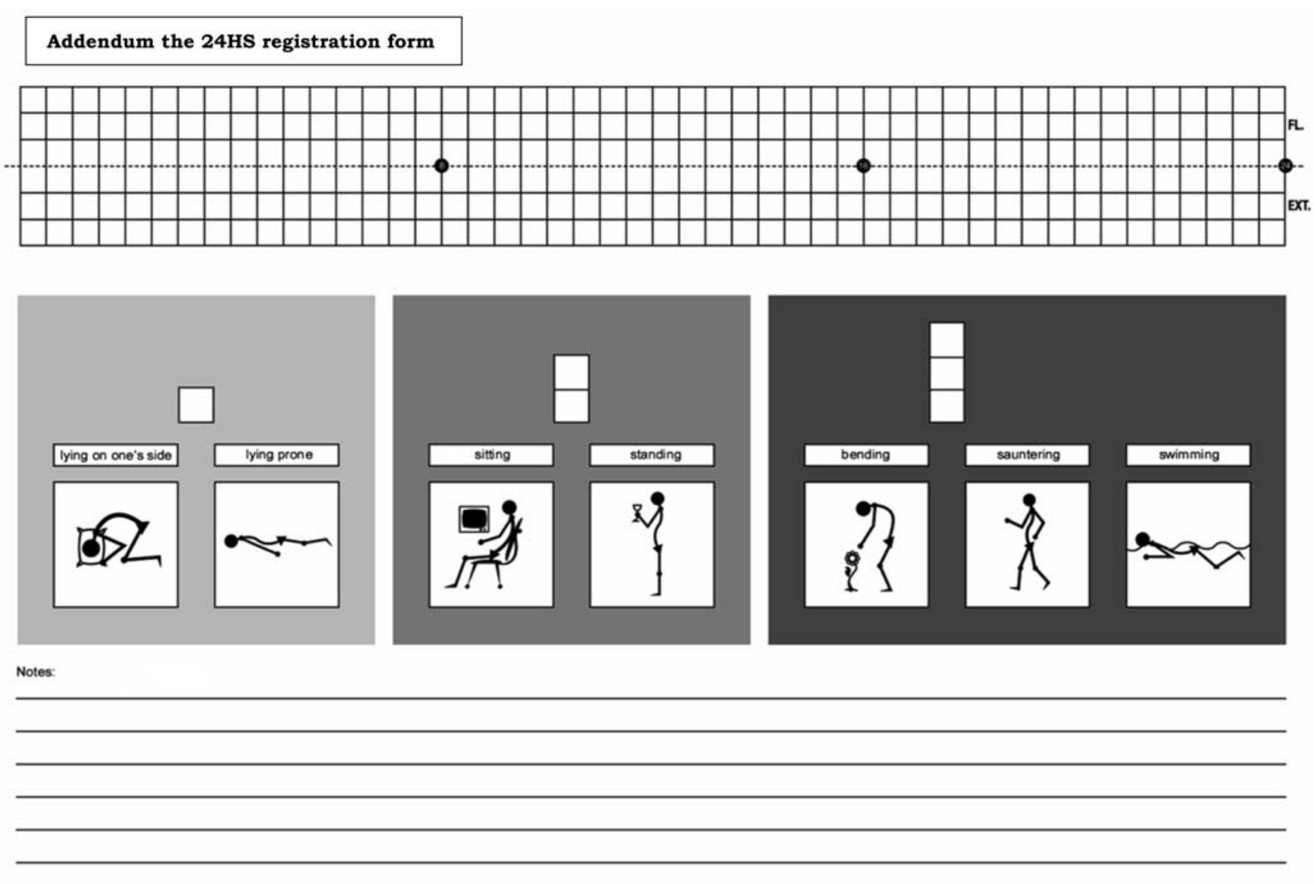


**Fig. 2** The 24HS registration form

## References


1. Adams MA, Hutton WC (1985) The effect of posture on the lumbar spine. J Bone Joint Surg (Br) 67(4):625–629
2. Adams MA, Dolan P, Hutton WC (1988) The lumbar spine in backward bending. Spine 13(9):1019–1026
3. Adams MA, Mannion AF, Dolan P (1999) Personal risk factors for first-time low back pain. Spine 24(23):2497–2505
4. Altman DG (1997) Relation between several variables. In: Altman DG (ed) Practical statistics for medical research. Chapman & Hall/CRC, Boca Raton, pp 325–361
5. Andersson GBJ (1997) The epidemiology of spinal disorders. In: Frymoyer JW (ed) The adult spine: principles and practice, 2nd edn. Raven Press, New York
6. Bakker EWP, Koning JCMF, Verhagen AP, Koes BW (2003) Interobserver reliability of the 24-Hour Schedule in patients with low back pain. JMPT 26(4):226–232
7. Croft PR, Papageorgiou A, McNally R (1997) Low back pain. Radcliffe Medical Press, Oxford
8. Croft PR, Macfarlane GJ, Papageorgiou AC, Thomas E, Silman AJ (1998) Outcome of low back pain in general practice: a prospective study. BMJ 316(7141):1356–1359
9. Dolan P, Adams MA, Hutton WC (1988) Commonly adopted postures and their effect on the lumbar spine. Spine 13(2):197–201
10. Erdman RA, Passchier J, Kooijman M, Stronks DL (1993) The Dutch version of the Nottingham Health Profile: investigations of psychometric aspects. Psychol Rep 72(3 Pt 1):1027–1035
11. Faas A, Chavannes AW, Koes BW, van den Hoogen JMM, Mens JMA, Smeele LJM (1996) NHG-standaard lage rugpijn. Huisarts Wet 39:18–31
12. Hartvigsen J, Leboeuf-Yde C, Lings S, Corder EH (2000) Is sitting-while-at-work associated with low back pain? A systematic, critical literature review. Scand J Public Health 28(3):230–239
13. Hartvigsen J, Bakketeig LS, Leboeuf-Yde C, Engberg M, Lauritzen T (2001) The association between physical workload and low back pain clouded by the ''healthy worker'' effect: population-based cross-sectional and 5-year prospective questionnaire study. Spine 26(16):1788–1793
14. Heliövaara M (1989) Risk factors for low back pain and sciatica. Ann Med 21:257–264
15. Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, Bouter LM (1999) Physical load during work and leisure time as risk factors for back pain. Scand J Work Environ Health 25(5):387–403
16. Jeaschke R, Singer J, Guyatt GH (1990) A comparison of seven-point and visual analogue scales. Control Clin Trials 11:43–51
17. Leboeuf-Yde C (1999) Smoking and low back pain. A systematic literature review of 41 journal articles reporting 47 epidemiologic studies. Spine 24(14):1463–1470
18. Lijmer JG, Mol BW, Heisterkamp S, Bonsel GJ, Prins MH, van der Meulen JH, Bossuyt PM (1999) Empirical evidence of design-related bias in studies of diagnostic tests. JAMA 282(11):1061–1066
19. Lings S, Leboeuf-Yde C (2000) Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992–1999. Int Arch Occup Environ Health 73(5):290–297
20. Linton SJ (2000) Psychological risk factors for neck and back pain. In: Nachemson A, Jonsson E (eds) Neck and back pain: the scientific evidence of causes, diagnosis, and treatment. Lippincott Williams & Wilkins, Philadelphia, pp 57–78
21. Mannion AF, Adams MA, Dolan P (2000) Sudden and unexpected loading generates high forces on the lumbar spine. Spine 25(7):842–852
22. McGill SM (1997) Distribution of tissue loads in the low back during a variety of daily and rehabilitation tasks. J Rehabil Res Dev 34(4):448-458
23. Nachemson A (1975) Towards a better understanding of low-back pain: a review of the mechanics of the lumbar disc. Rheumatol Rehabil 14(3):129–143
24. Netherlands Economic Illusions (2004) May 2nd 2002 survey: the economist print edition. http://www.economist.com/printedition/displayStory.cfm?Story_ID=1098153. Accessed November 11, 2004
25. Porterfield JA, DeRosa C (1998) Mechanical low back pain: perspectives in functional anatomy, 2nd edn. WB Saunders, Philadelphia, pp 1–22
26. Rossignol M, Abenhaim L, Feldman DE, Shrier I (2001) Risk factors for the development of low back pain in adolescence. Am Epidemiol 154(1):30–36
27. Waddell G (1987) A new clinical model for the treatment of low back pain. Spine 12:632–644
28. Ziektediagnosen bij uitkeringen voor arbeidsongeschiktheid: statistische informatie over medische classificaties in WAO, WAZ en Wajong 1999. Lisv 2001, Amsterdam, Lisv; 10. Available at: http://www.uwv.nl/Images/Ziektediagnosen%20bij%20AO%202002_tcm3–1739.pdf. Accessed November 3, 2004