Productivity Loss in the Workforce: Associations With Health, Work Demands, and Individual Characteristics

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Background *Decreased productivity at work is an important consequence of the presence of health problems at work.*

Methods *The study population consisted of 2,252 workers in 24 different companies in The Netherlands in 2005–2006 (response 56%). Self-reported loss of productivity on the previous workday was measured on a 10-point numerical rating scale by the Quantity and Quality method. Logistic regression analysis was used to explore the associations between work demands, health problems, individual characteristics, and lifestyle factors with the occurrence of productivity loss.*

Results *About 45% of the workers reported some degree of productivity loss on the previous workday, with an average loss of 11%. Moderate and severe functional limitations due to health problems (OR = 1.28 and 1.63, respectively) and lack of control at work (OR = 1.36) were associated with productivity loss at work with population attributable fractions of 7%, 6%, and 16%, respectively.*

Conclusion *Productivity losses at work frequently occur due to health problems and subsequent impairments, and lack of control over the pace and planning of work. This will substantially contribute to indirect costs of health problems among workers.* Am. J. Ind. Med. *© 2008 Wiley-Liss, Inc.*

KEY WORDS: health; lifestyle; productivity loss; work-related factors

INTRODUCTION

Hazardous work can result in injuries and work-related diseases, and subsequent consequences in terms of absenteeism and work disability [Benavides, 2006]. Compensation claims, disability and sickness absence have been considered as indicators to measure the health status of working populations [Berger et al., 2003]. However, evidence is emerging that health problems with subsequent functional limitations may also cause a decreased productivity while at work [Schultz and Edington, 2007]. Meerding et al. [2005] have shown that a reduced work productivity at work due to health problems was prevalent in 5–12% of construction workers and industrial workers, with an estimated mean loss of 12–28% in productivity. Among computer workers with musculoskeletal complaints while at work, productivity losses of 15% have been reported, whereby this reduced productivity exceeded the productivity loss due to sickness absence [Hagberg et al., 2002]. Brouwer et al. [1999] found that 7% of the workers in a trade company had health problems that reduced their productivity at work, resulting in an overall loss of 1% of all working hours during regular workdays. These findings indicate that the economic consequences of the occurrence of illness and disease are not limited to health care costs and sickness absence, but

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should also encompass the reduced productivity at work due to health complaints. The costs and benefits of allocation of interventions at the workplace will be substantially influenced by these indirect costs [Burdorf, 2007].

Apart from health problems, determinants of productivity loss may include individual characteristics of workers, lifestyle factors, job demands, and the work setting [Cockburn et al., 1999]. In one study an increased body mass index (BMI) was one of the most prominent causes of failure to maintain the productivity standard [Burton et al., 1999]. Other studies have also shown that obesity could have a negative impact on workers, not only through absenteeism but also through productivity loss at work [Bernaards et al., 2007; Gates et al., 2008]. In their review Schmier et al. [2006] presented indications that overweight or obese workers are at risk for higher productivity losses which may prompt employers to consider implementing health promotion programs to help employees achieve and maintain a healthy lifestyle.

Specific illnesses and diseases may lead to a reduced productivity while at work. Workers with migraine headache reported that 60–70% of their annual productivity losses of about 4.2 days was the result of an impaired performance while at work [Osterhaus et al., 1992; Schwartz et al., 1997]. Workers with osteoarthritis complaints during work time reported an average of 9% productivity loss [Lerner et al., 2002]. Work-related factors seem also important determinants of productivity loss. Having control in one's work, including being able to determine the pace of work, makes people more disposed to be present when having health problems, whereas those with a lower degree of control may more often be on sick leave [Aronsson and Gustafsson, 2005].

These studies have demonstrated that health problems at work can have substantial economic consequences since the health of workers will affect their ability to work. However, there is little insight into the relative importance of health, work-related factors, and individual characteristics for productivity loss at work. The main aims of this study were to evaluate the associations between health problems and productivity loss at work, and to evaluate the influence of work-related factors, lifestyle factors, and individual characteristics, on the associations between health problems and productivity loss at work.

MATERIALS AND METHODS

Study Population

The study population consisted of workers in 24 different companies who worked in 15 branches of industry in The Netherlands in 2005–2006. These different branches consisted of public administration, commercial services, health care, plastics industry, printing industry, power plants, construction industry, and agriculture. These companies had commissioned an occupational health organization to launch a program to investigate the employability of the workforce and as part of this program a questionnaire survey was conducted on health, work demands, work ability, and productivity. All companies participating in this program during 2 years enrolled all workers in the study population. The occupational health organization had send an invitation to all eligible workers by regular mail, and provided workers with an individualized password to fill out the questionnaire on a secure website. At time of enrolment informed consent was obtained from all participants to provide Erasmus MC for this specific study with their anonymous data in accordance with the Dutch Law for the Protection of Personal Data and the Code of Conduct for Medical Research [Federation of Biomedical Scientific Societies, 2004]. In this informed consent the occupational health organization ensured that all potentially identifying data, such as name of person, company or department, was removed from their database before data transfer, and Erasmus MC guaranteed strict confidentiality of individual, non-coded information. Complete data on productivity, work-ability, and health problems were available for 2,252 workers (1,214 blue-collar and 1,038 white-collar subjects). The response varied from 33% to 97% across companies with an overall response of 56%.

Productivity

The main outcome of this study was productivity loss, measured with the QQ method [Brouwer et al., 1999]. Respondents were asked to indicate how much work they actually performed during regular hours on their last regular workday as compared with normal. The quantity of productivity was measured on 10-point numerical rating scale with 0 representing "nothing" and 10 representing "normal quantity" [Brouwer et al., 1999; Meerding et al., 2005]. The median score on productivity was used as cut-off point to dichotomize workers into those with productivity loss (score less than 10) and those without (productivity score = 10). In their study Meerding et al. [2005] showed that the self-reported productivity in the QQ instrument correlated significantly with objective work output ($r = 0.48$).

Work-Related Factors

The work-related factors consisted of physical and psychosocial factors. The physical risk factors concerned the regular presence of manual materials handling such as lifting and carrying materials, awkward back postures in which the back is bent or twisted, static work postures, repetitive movements, and bending or twisting. A four-point scale was used with ratings "seldom or never," "now and then," "often," and "always" during a normal workday. The answers "often" and "always" were classified as high exposure [Elders and Burdorf, 2001].

Psychosocial risk factors were measured according to the demand–control model defined by Karasek et al. [1981,1998]. The three dimensions job control (5 items), skill discretion (3 items), and work demands (5 items) were assessed by an abbreviated version of the original questionnaire (Cronbach's alpha = 0.73) [Pelfrene et al., 2001]. Questions on job control concerned influence on the planning of tasks, influence on the pace of work, decisions about carrying out the tasks, interruption of work if necessary, and having a say on deadlines. Skill discretion concerned creativity, varied work, and required skills and abilities. Work demands related to excessive work, working hard, working fast, insufficient time to complete the work, and conflicting demands. For each questions, a four-point scale was used with ratings "seldom or never," "now and then," "often," and "always" during a normal workday. The sum score was calculated for each dimension separately and workers with a median sum score or higher were regarded as exposed to the psychosocial risk factor.

Health Problems

We used the work ability index (WAI) questionnaire to assess the workers' health [Tuomi et al., 1998]. This questionnaire consists of seven dimensions with a final index score ranging from 7 to 49, and divided into four work ability categories as poor (7–27 points), moderate (28–36 points), good (37–43 points), and excellent (44–49 points). Data were collected for each dimension separately. Dimensions 3 and 4 of the WAI are health-related questions. Dimension 3 is a limitative list of 13 broad categories of diseases, ever diagnosed by a physician, with dichotomous answers. Dimension 4 addressed current functional limitations due to health problems, based on an ordinal scale. Based on these dimensions, health was considered as: (1) number of reported diseases by workers, with categories of no disease, one disease, and more than one disease, and (2) currently present impairment at work due to diseases with categories no impairment, moderate impairment, and severe impairment. The workers were also asked about injuries due to accidents at work or in leisure time.

Individual Characteristic and Lifestyle Factors

Data on age, job type, height, and weight were collected by a questionnaire. Age was divided into three categories: 18–39, 40–49, and 50–65 years. The information on job type was used to classify subjects as either blue-collar or white-collar workers. The BMI was calculated by dividing body weight in kilogram by the square of body height in meters and used to define subjects as normal (BMI below 25), overweight (BMI from 25 to 30), or obese (BMI above 30). The lifestyle factors of interest concerned smoking and physical activity during leisure time. Subjects were divided in non-smokers and current smokers. They also were asked about their leisure time physical activity by a single yes/no question on the frequency of physical activities for at least 30 min during leisure time. Those who reported physical activity for 30 min per day on at least 5-day per week were considered in agreement with the recommendation on moderate physical activity [Pate et al., 1995].

Statistical Analysis

For the main variables we generated descriptive statistics such as numbers and percentages. Logistic regression analysis was used to explore the associations between work demands, health problems, individual characteristics and lifestyle factors with the occurrence of productivity loss at work. The odds ratio (OR) was estimated as the measure of association. For the initial selection of relevant variables, all variables with a P-value less than 0.20 were selected in univariate analyses. Subsequently, all variables selected in the univariate analyses were investigated in a multivariate analysis and retained in the multivariate analysis when statistically significant at $P < 0.05$. In the analysis age and sex were considered to be potential confounders and included in each multivariate model. Other variables were also considered as potential confounders and included in the multivariate model when introducing a change by $\geq$15% in the coefficient of other risk factors in the model. The Chi-square statistics was used to find interactions terms between work-related factors and health problems, by calculating the differences between the overall Wald test in models with interaction and models without, taking into account the differences in degree of freedoms. All analyses were carried out with the statistical package SAS version 8.2 [SAS, 1991–2001].

Population attributable fractions were calculated for significant determinants of productivity loss, using the formula $PAF = Pe\ (OR - 1)/(1 + Pe\ (OR - 1))$, with Pe representing the prevalence of the determinant in the study population [Hennekens and Mayrent, 1987; Rahman et al., 2005].

RESULTS

Data on descriptive characteristics of the workers in the study are presented in Table I. The mean age of the study population was 43 years, ranging from 18 to 65 years. The mean BMI of the respondents was 25.5 ($\pm$4.1). About 45% of the workers reported some degree of productivity loss on the previous workday. The mean score on the QQ quantity scale was 8.9, indicating an average loss of 11% compared with a

TABLE I. Baseline Characteristics of Workers (n = 2,252) in 24 Companies in The Netherlands

	N	%
Individual characteristics		
Age category		
18–39 years	753	33
40–49 years	696	31
50–65 years	803	36
Female (%)	697	31
White-collar	1,038	46
Life style factors		
Normal weight	1,105	49
Overweight	921	41
Obese	226	10
Current smoker	518	24
Sufficient physical activity in leisure time	1,321	60
Work-related factors		
Physical factors		
Manual materials handling	201	9
Awkward back postures	335	16
Static working postures	930	41
Repetitive movements	930	41
Bending and/or twisting upper body	751	33
Psychosocial factors		
Lack of job control	1,016	54
Poor skill discretion	1,601	71
High work demands	1,377	61
Health problem		
Number of diseases diagnosed		
0	612	27
1	609	27
2 and more	1,031	46
Work impairment due to health problems		
No impairment	1,443	64
Moderately impaired	575	26
Severely impaired	234	10
Productivity loss	1,018	45

regular workday. The median of the productivity score was 10 and only 10% of participants had a score less than 7. The mean scores of job control, skill discretion, and work demand were 6.6 (SD = 3.1), 3.5 (SD = 1.7), and 5.1 (SD = 2.5) respectively. The mean work ability among the study population was 41 (±5). The ORs and 95% confidence intervals (CI) for the likelihood of productivity loss were 1.63 (1.35–1.97), 2.66 (2.05–3.46), and 4.08 (2.36–7.07) for a good, moderate, and poor work ability, respectively, compared with an excellent work ability.

The most prevalent disease in the study population was musculoskeletal disease (45%). In the univariate analyses 9 out of 12 health problems showed an elevated OR, but only the occurrence of an accident and neurological problem showed statistically significant associations with productivity loss at work (Table II).

In the univariate analyses female and white-collar workers have a lesser chance for productivity loss than males and blue-collar workers (Table III). Although job type was significantly associated with productivity loss at work, it became non-significant (OR 0.96, 95% CI 0.74–1.25) when adjusted for health problems, lifestyle factors, and work-related factors. Smoking showed a significant association with lower productivity loss in both the univariate and multivariate analyses. Among the physical work factors, bending and/or twisting the upper body was significantly associated with productivity loss in the univariate analyses, but after adjustment for other variables this association became non-significant (OR 0.96, 95% CI 0.74–1.25). Poor skill discretion and lack of control showed significant association with productivity loss in the univariate analyses, but after control for other risk factors skill discretion became non-significant (OR = 1.20, 95% CI 0.98–1.46). Both health indicators (number of diseases diagnosed, and work impairments due to health) showed a positive association with productivity loss at work, but after adjustment only impaired workers showed a statistically significant association with productivity loss whereas number of diagnosed disease was of borderline significance (OR = 1.24, 95% CI = 0.99–1.54) (Table III). When introducing interaction terms between health problems and work-related factors in the logistic regression model, the goodness of fit of the model did not improve statistically significant.

The population attributable fractions for moderate and severe functional limitations due to health problems

TABLE II. Univariate Odds Ratios (OR) and 95% Confidence Intervals (CI) of History of Accident and Different Diseases for Productivity Loss Among Workers in Different Companies in The Netherlands (n = 2,252)

	N	%[a]	OR	95% CI
Accident	275	7	1.51	1.17–1.94*
Musculoskeletal disease	1,007	21	1.15	0.98–1.36
Cardiovascular disease	330	7	1.09	0.86–1.37
Respiratory disease	369	8	1.14	0.91–1.43
Psychological disease	248	6	1.27	0.97–1.65
Neurological disease	359	8	1.35	1.08–1.69*
Digestive system disease	220	5	1.27	0.96–1.67
Genitourinary disease	153	3	1.03	0.74–1.43
Skin disease	401	8	0.99	0.80–1.23
Tumor disease	68	1	1.09	0.67–1.77
Endocrine disease	136	3	0.96	0.98–1.36
Blood disease	73	1	0.95	0.60–1.53

*P-value <0.05.
[a]Percentage of workers with productivity loss.

TABLE III. Univariate and Multivariate Odds Ratios (OR) and 95% Confidence Intervals (CI) of Individual Characteristics, Life Styles Factors, Work-Related Factors, and Health Indicators for Productivity Loss Among Workers in Different Companies in The Netherlands (n = 2,252)

	Univariate analyses		Multivariate analysis	
	OR	95% CI	OR	95% CI
Age category				
18–39	1	—	1	—
40–49	0.93	0.76–1.14	0.90	0.73–1.10
50–65	0.81	0.67–1.00	0.78	0.64–0.97*
Sex	0.90	0.75–1.07	0.87	0.72–1.05
White-collar worker	0.73	0.62–0.86*		
Lifestyle factors				
Normal weight	1	—		
Overweight	1.14	0.96–1.36		
Obese	1.02	0.76–1.36		
Current smoker	0.78	0.64–0.95*	0.73	0.60–0.90*
Sufficient physical activity in leisure time	0.86	0.72–1.02		
Work-related factors				
Physical factors				
Manual materials handling	1.03	0.77–1.38		
Awkward back postures	1.05	0.84–1.32		
Static working postures	1.07	0.90–1.26		
Repetitive movements	0.95	0.80–1.12		
Bending and/or twisting upper body	1.21	1.01–1.44*		
Psychosocial factors				
Lack of job control	1.35	1.15–1.60*	1.36	1.14–1.63*
Poor skill discretion	1.21	1.00–1.45*		
High work demands	1.17	0.98–1.39		
Health problem				
Number of diseases diagnosed				
0	1	—		
1	1.31	1.04–1.64*		
2 and more	1.35	1.10–1.66*		
Work impairment due to health problems				
No impairment	1		1	
Moderately impaired	1.26	1.04–1.53*	1.28	1.05–1.56*
Severely impaired	1.58	1.19–2.08*	1.63	1.22–2.17*

*P-value <0.05.

were 7% and 6%, respectively. The population attributable fraction for lack of job control was 16%.

DISCUSSION

This study showed significant associations between health problems and subsequent impairments with productivity loss at work among workers in different companies in The Netherlands. Lack of job control was the most important factor associated with workers' productivity loss at work.

Some limitations must be considered in this study. First of all, the cross-sectional design of the study does not permit further explanation of the causal relationship between these factors and productivity loss at work. Secondly, there may have been some reluctance among participants to report symptoms and subsequent reduced productivity at work due to fears that if the employer would receive this information it could affect salary and employment. Although participants were informed that this information on productivity loss would remain strictly anonymous, it cannot be disregarded that some information bias might have occurred. Thirdly, the low response may also be associated with the presence of productivity loss. Unfortunately, we do not have information on response at company level, since companies hired the occupational health organization as external consultancy through different acquisition routes. Hence, it is not known whether these companies represent a random sample of the workforce in The Netherlands with respect to working conditions, health status, and work ability aspects. Within each company, it may be possible that workers with productivity loss have had less interest in participating in the study. In order to investigate the presence of potential selection bias in our study, the same analyses were done in 1,014 workers of 16 companies with a response of 80% and more. Since the results were almost the same, we think that this source of selection bias will not have influenced the results to a major extend. Finally, although another study has emphasized the effect of education and income on productivity loss [McCunney, 2001], the available data did not allow investigating the effect of these factors on productivity loss.

Work productivity can be related to a variety of factors such as work-related factors, and health problems [McCunney, 2001]. Productivity is most likely related to the physical work environment such as thermal climate and lighting condition and to regular disturbances in the logistics of the production process [Niemelä et al., 2002, 2006]. Although in the present study available data did not allow investigating the influence of the latter factors on productivity loss directly, the influence of the most important physical work-related factors was investigated. Our results showed that psychosocial factors at work played a more important role on decreased productivity at work than physical load factors. The most prominent psychosocial factor was lack of control in the job with an OR of 1.36 (1.14–1.63). This association remained unchanged when adjusted for other significant variables. Other studies have also reported a positive association between productivity loss at work and a reduced job control [Aronsson and Gustafsson, 2005; Meerding et al., 2005]. Under the assumption of a causal association between work-related factors and productivity loss, we estimated that about 16% of productivity losses were attributable to lack of control at work. One has to bear in mind, however, that a change in the cut-off value of this dichotomized factor might change the prevalence of exposure as well as the OR and, thus, lead to a different population attributable risk. It is hypothesized that workers with a high job control are more likely to be able to work with health problems, because they may be able to adapt their pace of work to their current state of health. Control over the pace of work enables the individual to adapt the task performance to his or her physical and mental condition ''on the day.'' It is also possible that workers with better control on their job may compensate the productivity loss in overtime.

The health status of workers is an important underlying factor in enhancing or maintaining productivity in the labor force [Koopmanschap et al., 2005]. We observed that health problems per se had a lesser importance than the presence of impairments due to these health problems. Although in the univariate analyses both indicators of health—number of diseases and work impairment due to health—were positively associated with productivity loss, in the multivariate analysis only work impairment remained significant, although number of diagnosed diseases was of borderline statistical significance. Under the assumption of a causal relationship between health problems and productivity loss, approximately 7% of productivity loss was attributed to moderate functional limitations due to health problems. The population attributable fraction of productivity loss for severe functional limitations due to health problems was 6%. It should be noted that the number of diseases in the WAI questionnaire refers to diseases diagnosed in the past without a clear definition of the recall period, whereas work impairment was defined as an experienced hindrance in the current job. Therefore, this difference in recall period may explain why impairments were more important than the occurrence of diseases. This finding suggests that coping mechanisms with health at the work place are likely to play an important role in maintaining a good productivity at work. In addition of maintaining productivity, it has been shown that a positive coping mechanism also prevented withdrawal from the labor force in patients with rheumatoid arthritis [Chorus et al., 2001; Boonen et al., 2004].

Musculoskeletal problems were the most common diseases among the study population (45%). Our result showed a comparable finding as Hagberg et al. [2002] who reported a mean reduction of productivity of about 15% for women and 13% for men due to musculoskeletal diseases, but this effect in our analysis was of borderline significance (OR = 1.15, 95% CI 0.98–1.36). Meerding et al. [2005] also reported an average productivity loss of 7% for industrial workers and 25% for construction workers with musculoskeletal diseases. It has been also shown that pain from arthritis, back pain and other musculoskeletal problems caused productivity loss among 13% of US workers [Stewart et al., 2003]. A possible explanation for the non-significant finding in our study is that the majority of musculoskeletal symptoms were not present on the previous workday or may have had no relation to work activity. The latter is suggested by a population survey where a wide variety of musculoskeletal symptoms were unrelated to work activity [Pastides, 1995]. Secondly, in various jobs productivity at work may have been influenced more by external factors, such as characteristics of the production process, most notably working in teams or in processes that are not machine-paced. Since about 50% of our study populations were blue-collar workers, it was hypothesized that work-related physical load in combination with musculoskeletal problems would influence productivity loss. The lack of a statistically significant interaction suggests that these musculoskeletal problems only influenced productivity when there is no possibility to adjust work activities, as was demonstrated by the importance of lack of control.

The individual characteristics included in the analysis—age and gender—had no associations with productivity loss at work. A study on determinants of presenteeism, the phenomenon that workers turn up at work despite health problems [Burton et al., 2004; Dew et al., 2005], also showed no significant influence of these individual characteristics [Aronsson and Gustafsson, 2005].

Although in the univariate analysis white-collar workers had less productivity loss than blue-collar workers, after adjustment for other determinants, this association became non-significant. One previous study showed that blue-collar workers have a somewhat higher presenteeism than white-collar workers, but this finding could not be corroborated in our study [Aronsson et al., 2000]. Since the occurrence of health problems was higher among blue-collar workers, after adjustment for health status, the independent effect of job type disappeared. Although one study found that moderate and vigorous exercise levels were associated with important work outcomes [Pronk et al., 2004] the relationship between productivity loss and physical activity in leisure time was not statistically significant. Another study also failed to show a significant relationship between physical activity and productivity loss at work [Bernaards et al., 2007]. A surprising finding in our study was that smokers reported less productivity loss at work (OR 0.73, 95% CI 0.60–0.90). This contradicts the finding of Bunn et al. [2006] who reported that current smokers incurred the highest health-related productivity losses when compared with non-smokers and former smokers, although in their study productivity losses comprised both absenteeism and productivity loss at work. Our result might be partly due to reporting bias. Due to legislation in all workplaces a stringent smoke free policy has been adopted in the past few years in The Netherlands. In the debate on this legislation potential productivity loss at work among smokers played a substantial role and, hence, this may have biased the answers.

We found that productivity loss was associated with sick leave (data not shown). In The Netherlands everyone on sickness absence will be paid a full salary for the first 12 months of sickness absence. Therefore, financial pressure cannot be an explanation for productivity loss while at work. Since in the workers with reduced productivity, sick leave will provide a scope for physical and psychosocial recuperation following strain or disease [Aronsson et al., 2000], it can be expected that workers with productivity loss at work are at higher risk for future sick leave [Lotters et al., 2005].

In conclusion, this study demonstrated that productivity losses at work frequently occurred and were partly related to health problems and subsequent impairments. This loss of productivity will substantially contribute to indirect costs of diseases among workers and may prompt for interventions at the workplace. Job control was the most important work-related factor for maintaining good productivity. Hence, health management at the workplace should consider interventions that increase the possibilities for workers with health problems to continue working according to their abilities.

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REFERENCES

Aronsson G, Gustafsson K. 2005. Sickness presenteeism: Prevalence, attendance-pressure factors, and an outline of a model for research. J Occup Environ Med 47:958–966.

Aronsson G, Gustafsson K, Dallner M. 2000. Sick but yet at work. An empirical study of sickness presenteeism. J Epidemiol Community Health 54:502–509.

Benavides FG. 2006. Ill health, social protection, labour relations, and sickness absence. Occup Environ Med 63:228–229.

Berger ML, Howell R, Nicholson S, Sharda C. 2003. Investing in healthy human capital. J Occup Environ Med 45:1213–1225.

Bernaards CM, Proper KI, Hildebrandt VH. 2007. Physical activity, cardiorespiratory fitness, and body mass index in relationship to work productivity and sickness absence in computer workers with preexisting neck and upper limb symptoms. J Occup Environ Med 49:633–640.

Boonen A, Van Der Heijde D, Landewe R, Chorus A, Van Lankveld W, Miedema H, Van Der Tempel H, Van Der Linden S. 2004. Is avoidant coping independent of disease status and stable over time in patients with ankylosing spondylitis? Ann Rheum Dis 63:1264–1268.

Brouwer WB, Koopmanschap MA, Rutten FF. 1999. Productivity losses without absence: Measurement validation and empirical evidence. Health Policy 48:13–27.

Bunn WB III, Stave GM, Downs KE, Alvir JM, Dirani R. 2006. Effect of smoking status on productivity loss. J Occup Environ Med 48:1099–1108.

Burdorf A. 2007. Economic evaluation in occupational health—Its goals, challenges, and opportunities. Scand J Work Environ Health 33: 161–164.

Burton WN, Conti DJ, Chen CY, Schultz AB, Edington DW. 1999. The role of health risk factors and disease on worker productivity. J Occup Environ Med 41:863–877.

Burton WN, Pransky G, Conti DJ, Chen CY, Edington DW. 2004. The association of medical conditions and presenteeism. J Occup Environ Med 46:S38–45.

Chorus AM, Miedema HS, Wevers CW, van der Linden S. 2001. Work factors and behavioural coping in relation to withdrawal from the labour force in patients with rheumatoid arthritis. Ann Rheum Dis 60:1025–1032.

Cockburn IM, Bailit HL, Berndt ER, Finkelstein SN. 1999. Loss of work productivity due to illness and medical treatment. J Occup Environ Med 41:948–953.

Dew K, Keefe V, Small K. 2005. 'Choosing' to work when sick: Workplace presenteeism. Soc Sci Med 60:2273–2282.

Elders LA, Burdorf A. 2001. Interrelations of risk factors and low back pain in scaffolders. Occup Environ Med 58:597–603.

Federation of Biomedical Scientific Societies. 2004. Code of conduct for Use of Data in Health Research. http://www.federa.org [Accessed May 19, 2008].

Gates DM, Succop P, Brehm BJ, Gillespie GL, Sommers BD. 2008. Obesity and presenteeism: The impact of body mass index on workplace productivity. J Occup Environ Med 50:39–45.

Hagberg M, Tornqvist EW, Toomingas A. 2002. Self-reported reduced productivity due to musculoskeletal symptoms: Associations with workplace and individual factors among white-collar computer users. J Occup Rehabil 12:151–162.

Hennekens CHBJ, Mayrent SL. 1987. Epidemiology in medicine. Boston: Lippincott Williams & Wilkins. p 383.

Karasek R, Baker D, Marxer F, Ahlbom A, Theorell T. 1981. Job decision latitude, job demands, and cardiovascular disease: A prospective study of Swedish men. Am J Public Health 71:694–705.

Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. 1998. The Job Content Questionnaire (JCQ): An instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol 3:322–355.

Koopmanschap M, Burdorf A, Jacob K, Meerding WJ, Brouwer W, Severens H. 2005. Measuring productivity changes in economic evaluation: Setting the research agenda. Pharmacoeconomics 23:47–54.

Lerner D, Reed JI, Massarotti E, Wester LM, Burke TA. 2002. The Work Limitations Questionnaire's validity and reliability among patients with osteoarthritis. J Clin Epidemiol 55:197–208.

Lotters F, Meerding WJ, Burdorf A. 2005. Reduced productivity after sickness absence due to musculoskeletal disorders and its relation to health outcomes. Scand J Work Environ Health 31:367–374.

McCunney RJ. 2001. Health and productivity: A role for occupational health professionals. J Occup Environ Med 43:30–35.

Meerding WJ, IJzelenberg W, Koopmanschap MA, Severens JL, Burdorf A. 2005. Health problems lead to considerable productivity loss at work among workers with high physical load jobs. J Clin Epidemiol 58:517–523.

Niemelä R, Rautio S, Hannula M, Reijula K. 2002. Work environment effects on labor productivity: An intervention study in a storage building. Am J Ind Med 42:328–335.

Niemelä R, Seppänen O, Korhonen P, Reijula K. 2006. Prevalence of building-related symptoms as an indicator of health and productivity. Am J Ind Med 49:819–825.

Osterhaus JT, Gutterman DL, Plachetka JR. 1992. Healthcare resource and lost labour costs of migraine headache in the US. Pharmacoeconomics 2:67–76.

Pastides H. 1995. An epidemiological perspective on environmental health indicators. World Health Stat Q 48:140–143.

Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC, Kriska A, Leon AS, Marcus BH, Morris J, Paffenbarger RS, Patrick K, Pollock ML, Rippe JM, Sallis J, Wilmore JH. 1995. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 273:402–407.

Pelfrene E, Vlerick P, Mak R, De Smet P, Kornitzer M, De Backer G. 2001. Scale reliability and validity of Karasek 'Job Demand-control-support' model in Belstress. Work Stress 15:297–331.

Pronk NP, Martinson B, Kessler RC, Beck AL, Simon GE, Wang P. 2004. The association between work performance and physical activity, cardiorespiratory fitness, and obesity. J Occup Environ Med 46:19–25.

Rahman M, Sakamoto J, Fukui T. 2005. Calculation of population attributable risk for bidi smoking and oral cancer in south Asia. Prev Med 40:510–514.

SAS. 1991–2001. SAS software version 8.2, 8.2 edition. Cary, NC, USA: SAS Institute.

Schmier JK, Jones ML, Halpern MT. 2006. Cost of obesity in the workplace. Scand J Work Environ Health 32:5–11.

Schultz AB, Edington DW. 2007. Employee health and presenteeism: A systematic review. J Occup Rehabil 17:547–579.

Schwartz BS, Stewart WF, Lipton RB. 1997. Lost workdays and decreased work effectiveness associated with headache in the workplace. J Occup Environ Med 39:320–327.

Stewart WF, Ricci JA, Chee E, Morganstein D, Lipton R. 2003. Lost productive time and cost due to common pain conditions in the US workforce. JAMA 290:2443–2454.

Tuomi KIJ, Ilmarinen J, Jahkola A, Katajarinne L, Tulkki A. 1998. work ability index. Helsinki: Finnish Institute of Occupational Health.