Associations between the Occupational Stress Index and Hypertension, Type 2 Diabetes Mellitus, and Lipid Disorders in Middle-Aged Men and Women

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Received 20 April 2011; in final form 9 July 2012; published online 17 September 2012

Introduction: Retrospective and prospective studies show that stress at work is linked to an increased risk of hypertension, diabetes mellitus, and coronary heart disease. However, the nature of the contributory job stressors and biological mechanisms need further elucidation.

Objectives: The study is aimed to determine the associations between aspects of the occupational stress index (OSI) and arterial hypertension, diabetes mellitus (DM) type 2, and lipid disorders in working middle-aged men and women.

Methods: The cross-sectional study involved 989 middle-aged men and women in different occupations. The OSI was calculated by using standardized questionnaires. The total participation rate was 93%. Occupational stressors were divided into seven groups: High Demands, Strictness, Underload, Extrinsic Time Pressure, Noxious Exposure, Avoidance, and Conflict/Uncertainty. Serum lipid levels, glucoregulation, blood pressure, and cardiovascular risk factors were measured.

Results: For both women and men, the total OSI score associated significantly with DM (women: odds ratio [OR] 2.4, 95% confidence intervals [CI] 1.67–3.45; men: 1.21, 1.15–1.45), any type of dyslipidemia (women: 1.54, 1.17–2.03; men: 1.31, 1.24–1.39), and arterial hypertension (women: 1.15, 1.10–1.21; men: 1.58, 1.49–1.68). The group as a whole showed associations between total OSI and low high-density lipoprotein (HDL) cholesterol, high total cholesterol, and high triglyceride levels. Of the OSI aspects, Underload associated significantly in both men and women with arterial hypertension (women: 3.48, 1.91–6.31; men: 2.71, 1.96–3.75) and dyslipidemia (women: 3.26, 2.13–4.99; men: 2.11, 1.76–2.52). Underload was also associated with several lipid abnormalities in the group as a whole. It associated with DM in women only (4.7, 2.84–7.81). All remaining OSI aspects also associated significantly and positively with DM in women only. Conversely, in male workers, but not female workers, High Demand, Conflict/Uncertainty, and Extrinsic Time Pressure associated significantly with arterial hypertension. Strictness and Conflict/Uncertainty associated positively with dyslipidemia in women only. Noxious Exposures associated positively with DM and arterial hypertension in women only.

Conclusions: The study provides evidence for the association of work stress with metabolic disorders and hypertension. Total OSI associated significantly with DM type 2, arterial hypertension, and dyslipidemia in both genders. Different OSI aspects associated with these health issues in gender- and occupational-specific patterns. Underload, which represents lack of social communication, simple task preparation, and underestimation of working results, associated most strongly of all OSI aspects with disease in both the sexes.

Keywords: diabetes mellitus; dyslipidemia; hypertension; lipid disorders; occupational diseases; occupational stress index; stress

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INTRODUCTION

Stress can be defined as a process where environmental stimuli place undue strain on a human being, resulting in psychological and physiological changes that increase the risk of disease. Psychological stress has been identified as a possible factor in the etiology of heart disease (Möller et al., 2005).

Observational studies of human populations show that occupational stress is a source of life stress that can influence blood pressure levels (Radi et al., 2005). Stress at work has also been linked with an increased risk of hypertension and coronary heart disease in retrospective and prospective studies (Su et al., 2001; Rosengren et al., 2004). Plausible pathophysiological mechanisms that have been proposed involve not only unhealthy lifestyle habits and behaviors but also the dysregulation of neuroendocrine pathways that lead to visceral obesity and insulin resistance (Brunner et al., 2002; Hemingway et al., 2005). This is supported by studies that found a connection between exposure to work stress and the metabolic syndrome (Chandola et al., 2006; Akbaraly et al., 2009). Cross-sectional studies have also linked work stress with lipid disorders and diabetes mellitus (DM), but this association is not consistently observed (Siegrist and Peter, 1997; Peter et al., 1998; Greenlund et al., 2010).

There is relatively little information regarding the impact of psychosocial factors on the future risk of DM type 2 and lipid disorders. The effect of psychosocial working conditions on health can be analyzed by applying the job demand control model of Karasek. This model allows one to measure the occupational stress that is due to a combination of psychosocial demands, decision latitude (job control), and social support at work, which in turn allows one to determine the impact of occupational stress on the risk of disease (Hemingway et al., 2005). An alternative way to conceptualize work stress is the effort–reward imbalance model. Investigators in the Whitehall II Study showed that effort–reward imbalance and low social position, but not low job control or high job demands, were associated with incident DM type 2 (Kumari et al., 2004).

However, the evidence linking occupational stress to a higher prevalence of cardiovascular diseases (CVDs) is inconsistent, which suggests that new tools should be developed to assess occupational stress. The occupational stress index (OSI) incorporates key aspects of the leading sociological work stress models, namely job strain and effort–reward imbalance, but was developed from the perspective of cognitive ergonomics. Cognitive ergonomics addresses how human beings process information, make decisions, and carry out actions. In the OSI, the work environment is viewed as a whole: it measures task-level issues, work schedule, and physical, chemical, and broader organizational factors, all of which contribute to the total burden. In total, 80 equally weighted elements are measured. These are organized into seven OSI aspects, and summing the element scores thus yields OSI aspect scores. These scores are then summed themselves to yield the total OSI score (Belkic and Nedic, 2007). Further analysis of how the OSI aspects associate with cardiovascular risk factors and coronary heart disease in different occupational groups could improve our understanding of the pathogenetic influence of various occupational stresses.

OBJECTIVES

The present study was conducted to determine how OSI aspects and the total OSI score associate with arterial hypertension, DM type 2, and lipid disorders in middle-aged men and women in several different occupations.

METHODS

This cross-sectional study was performed during 2008–2010 and included 989 middle-aged men and women (aged 35–60 years) who were divided into 7 occupational subgroups, namely 193 electronic industry workers, 102 metal industry workers, 101 construction workers, 154 bank workers, 194 bus drivers, 123 truck drivers, and 122 professional taxi drivers. The representativeness of the sample size was calculated by assuming that a minimal sample size of 650 would ensure a confidence level of 99% with a 5% margin of error. The 989 workers were selected from the worker population that is served by the Institute of Occupational Health in Niš, where this research was conducted. This worker population consists of about 5000 workers in different industries and 3000 workers in the tertiary sector. In total, 1060 workers were randomly selected and invited to participate in the study: 200 in the electronic industry, 110 in the metal industry, 110 in construction, 180 in banking, 200 bus drivers, 130 truck drivers, and 130 taxi drivers. The electronic industry workers mainly worked on assembly lines. The metal industry workers worked with an industrial machine. The construction workers mainly did outdoor jobs, while the banking workers mainly had sitting jobs and worked...
at counters. The subjects were recruited randomly during systematic preventive examinations, which are standard work-related procedures performed by specialized dispensaries in the Institute of Occupational Health in Niš. The subjects were asked to complete a standardized questionnaire that asked questions about the working conditions and occupational stressors. They also underwent a medical examination and their medical records were analysed. The resulting seven occupational subgroups did not differ from the general occupational populations from which they were selected in terms of gender or age distribution. These seven occupational groups were chosen because they undergo regular systematic preventive examinations and are representative of the main industrial branches and tertiary sectors in the region.

Workers of both sexes aged between 30 and 60 years were included in the study if they had permanent positions and had been employed for at least 3 years in their current occupation. Workers with acute or chronic inflammatory diseases, immune and major systemic diseases, structural non-ischemic heart disease, a history of myocardial infarction, myocardial revascularisation procedures, cerebrovascular diseases, secondary hypertension, chronic kidney, and liver or other important chronic diseases were excluded from the study.

The overall participation rate was 93.3%, while the participation rates for the individual occupations were as follows: 96.5% in the electronic industry, 92.7% in the metal industry, 91.8% in construction, 85% in banking, 97% for bus drivers, 94.6% for truck drivers, and 93.8% for taxi drivers. In total, 41 men did not finish the examination: 17 refused to participate, 3 did not sign informed consent forms, 12 were insufficiently literate, and 9 did not return the questionnaire, or did so with incomplete responses. These subjects were excluded. In total, 30 women did not finish the examination: 22 refused to participate and 8 did not return the questionnaire, or did so with incomplete responses. These subjects were excluded. The participation rate according to gender was 93.7% for males and 91.1% for females.

The presence and the intensity of occupational stressors were analysed by using the standardized questionnaire and then by calculating the total stress load index according to Belkić (2003). The research was conducted during working days at a worksite clinic where the ambulatory blood pressure was read and blood was sampled.

The OSI

The OSI was calculated by using the standardized questionnaires authorized by Belkić (2003). The Yugoslav/Serbian versions of the OSI were used. These have been prepared by using translation/back-translation and have been validated (Brislin et al., 1973). The professional driver-specific OSI questionnaire was used with the bus, truck, and taxi drivers. The generic OSI questionnaire was used with the workers in the electronic and metal industries, construction, and banking. The questionnaire was completed by the participants in an anonymous fashion. If missing clinical data (lipid levels and hypertensive and diabetic statuses) were discovered after reviewing the questionnaires, then blind interviews were conducted to obtain the missing data. If the questionnaire data were inconsistent or the participant showed weak compliance to help complete the missing data, then the questionnaire was rejected.

The OSI model is arranged as a two-dimensional matrix: the vertical axis consists of four levels of information transmission, while the horizontal axis involves seven stressor aspects. The box where a particular information transmission level intersects with a particular stressor aspect contains one or more elements. The 80 elements are equally weighted as they are scored using a 0 to 2 scale, where 0 means absent and 2 means strongly present. Higher scores thus indicate a higher level of burden. The element scores of the individual OSI aspects are summed to yield the aspect scores. Each aspect has a different number of elements: Underload has 11, High Demand has 20, Strictness has 11, Extrinsic Time Pressure has 5, Aversiveness/Noxious Exposures has 7, Avoidance (Symbolic Aversiveness/Disaster Potential) has 9, and Conflict/ Uncertainty has 15. Thus, the minimum and maximum scores of each aspect differ. The aspect scores are then summed to generate the total OSI score, which reflects the overall burden from work stressors (Nedić et al., 2010). The OSI is based on a questionnaire, but worksite measurements and other available data can be incorporated to improve its accuracy and precision (Belkić et al., 1995). In this study, information was obtained from ‘medical charts’, worksite measurements, and expert observations about nightshift work, number of work hours, vacation time, moonlighting, and exposure to physical and chemical toxins.

The OSI questionnaire was used in a cross-sectional prevalence study design. The use of this questionnaire requires the permission of the author, Dr. Karen Belkic (2003).

Determination of serum lipids and glucoregulation

Overnight fasting venous blood sample was taken between 8:00 and 9:00 am. After the serum was
indicated hypercholesterolemia was a TC level of \( \geq 5.18 \text{ mmol l}^{-1} \). The cut-off point that indicated low HDL cholesterol levels in men and women were \(<1.04 \text{ mmol l}^{-1}\) and \(<1.3 \text{ mmol l}^{-1}\), respectively. The cutoff point that indicated hypertriglyceridemia was a TG level of \( \geq 1.7 \text{ mmol l}^{-1} \). The cut-off points indicating low HDL cholesterol levels in men and women were \(<1.04 \text{ mmol l}^{-1}\) and \(<1.3 \text{ mmol l}^{-1}\), respectively. The cutoff point that indicated hypertriglyceridemia was a TG level of \( \geq 2.37 \text{ mmol l}^{-1} \). High LDL cholesterol was indicated by the \( \geq 3.18 \text{ mmol l}^{-1} \) cutoff. Workers with a history of specific treatment for lipid abnormality (based on self-reporting in the questionnaire and/or the clinical records of the workers) and workers who had one or more abnormal serum lipid concentrations were classified as dyslipidemic and were included in the analysis (Grundy et al., 2004, 2006). Of these dyslipidemic workers, 10.2% had a history of lipid abnormality treatment or had clinical records showing abnormal serum lipid concentrations, and 89.8% had abnormal serum lipid levels. Cases with a history of specific lipid abnormality treatment were not included in the analysis of the associations between the OSI and specific lipid disorders.

Fasting glucose concentrations in capillary plasma were measured on an Axon–Bayer analyser. DM type 2 was defined according to American Diabetes Association—ADA diagnostic criteria (2003) as fasting blood glucose \( >7.0 \text{ mmol l}^{-1} \). This accounted for 55.9% of all diabetic workers in the study. A worker was also deemed to have DM type 2 if there was the use of insulin or oral hypoglycemic agents, a self-reported history of diabetes, or if it was stated in the clinical records of the worker. This accounted for the remaining 44.1% of the diabetic workers. Workers with type 1 DM were excluded from the study on the basis of anamnestic patient data and their medical records.

**Blood pressure measurement and hypertension**

On arrival, the subjects remained in a resting (sitting) position for 5 min before starting measurements. Blood pressure in the left upper arm was measured three times by auscultation (sphygmomanometer and stethoscope, Becton Dickinson, USA) in accordance with the American Heart Association procedure, and the average was calculated (Pickering et al., 2005). The appropriate cuff-size was used for blood pressure measurements on the basis of the minimal width of one-third of the upper arm. The health practitioners were trained and certified to ensure consistent handling of the equipment and consistent reading procedures across individuals. Hypertension was defined according to WHO criteria as systolic blood pressure \( \geq 140 \text{ mmHg} \) and/or diastolic blood pressure \( \geq 90 \text{ mmHg} \). Of the hypertensive workers, 4.1% were newly diagnosed in this fashion. Individuals were also considered to be hypertensive if they were currently taking antihypertensive therapy, as indicated by self-reporting in the questionnaire and their clinical records (Chobanian et al., 2003). This accounted for the remaining 95.9% of the hypertensive workers.

**Consent and data security**

All participants in this study were informed about the purpose and benefits of the project, the research methods, the potential risks or hazards of participation, and their right to ask for additional information any time during the research procedure. They were also informed that their choice to participate was on a voluntary basis and that they were free to withdraw from the research project at any time. All phases, testing, and reports of the study were approved by the Institute for Occupational Safety and Health Internal Review Board. Written informed consent was obtained from all participants, and confidentiality was guaranteed for all participants.

**Statistics**

The continuous variables are presented as mean ± S.D. The categorical variables were expressed as frequencies. Differences between groups in terms of continuous and categorical variables were tested by ANOVA and \( \chi^2 \) test, respectively. To avoid the impact of antihypertensive, antidiabetic, and hypolipidemic therapy on relevant parameters, clinical diagnostic criteria were used to define binary outcome variables and hence logistic regression was applied. Correlations between OSI aspects were calculated by bivariate correlation analysis and indicated by Pearson’s correlation coefficient. Associations between the OSI aspects and arterial hypertension, DM type 2, and dyslipidemia were determined by sex-stratified age-adjusted logistic regression analysis. All OSI aspects were entered together and the enter model was used. The total OSI was analysed separately. The presented data were obtained after
adjusting the odds ratio (OR) with the 95% confidence interval (CI) and the corresponding P-values. A P-value of <0.05 was considered to be statistically significant. SPSS 11.5 software (SPSS Inc., Chicago, USA) was used for statistical analyses.

RESULTS

As shown in Table 1, the seven occupational groups that were examined had the same mean ages but differed significantly in terms of gender distribution, smoking habit, presence of a family history of coronary artery disease (CAD), medical history, diagnosed hypertension, and DM. The occupational groups also differed significantly in terms of OSI aspect scores as well as the total OSI scores.

As shown in Table 2, the OSI aspects correlated strongly with each other. Underload and Avoidance/Symbolic Aversiveness correlated positively with each other, but inversely with all other OSI aspects except Aversiveness/Noxious Exposures. Noxious Exposures correlates negatively with the other four aspects: High Demand, Strictness, Conflict/Uncertainty, and Extrinsic Time Pressures. The other aspects mainly correlated with each other in a positive manner.

Tables 3–6 show the results of the binary regression analysis with multiple OSI aspects entered together. In both men and women, significant positive associations were detected between several OSI aspects and hypertension (Table 3). For both genders, Underload associated the most strongly with arterial hypertension. In women, Aversiveness/Noxious Exposures associated significantly with arterial hypertension. By contrast, in male workers, High Demand, Conflict/Uncertainty, and Extrinsic Time Pressure associated significantly with arterial hypertension. The total OSI also associated significantly with arterial hypertension in both genders.

With regard to DM, there were a number of significant gender-related associations between OSI aspects and DM (Table 4). In females, all aspects and the total OSI associated significantly with DM. Again, Underload associated most strongly with

<table>
<thead>
<tr>
<th>Table 1. Baseline characteristics of the six worker groups.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Baseline, n</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Male/female</td>
</tr>
<tr>
<td>Smoker, n/%</td>
</tr>
<tr>
<td>Family history of CAD, n/%</td>
</tr>
<tr>
<td>HTA, n/%</td>
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<tr>
<td>DM type 2, n/%</td>
</tr>
<tr>
<td>Dyslipidemia</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD or n%; CAD, coronary artery disease; HTA, arterial hypertension; DM, diabetes mellitus; OSI, occupational stress index.
Conflict/Uncertainty, Avoidance/Symbolic Aversiveness, and Extrinsic Time Pressure associated more strongly with DM than the total OSI. In males, only total OSI associated significantly with DM.

In terms of dyslipidemia of any type, Underload showed a significant positive association in both genders, while Aversiveness/Noxious Exposures associated negatively in both genders (Table 5). Strictness and Conflict/Uncertainty showed significant positive associations with dyslipidemia in women only. Total OSI exhibited significant positive associations with dyslipidemia in both genders.

In all participants as a group, including those on lipid-lowering medications, Underload showed a significant positive association with low HDL, high TC, and high LDL (Table 6). Aversiveness/Noxious Exposures associated inversely with low HDL, high TC, and high TG. Avoidance/Symbolic Aversiveness and Extrinsic Time Pressure associated with some lipid abnormalities but the remaining OSI aspects did not associate significantly with any dyslipidemia measurements. The total OSI score associated significantly and positively with low HDL, high TC, and high TG.

**DISCUSSION**

The middle-aged workers who participated in the present study had a high prevalence of cardiovascular risk factors, namely a family history of CAD, smoking, arterial hypertension, DM, and dyslipidemia (Table 1). This is in line with data from the National Registry of Cardiovascular Diseases, which show that cardiovascular diseases are the leading cause of mortality in Serbia (56%). Of the patients with acute coronary syndrome in the district of Nis, 53.8% have a family history of CAD, 19.1% are obese, 17.1% are stressed, 43.9% smoke, 47.3% have dyslipidemia, 70.8% have hypertension, and 29.4% have DM (Serbian acute coronary syndrome registry report, 2007). In the present study, adoption of the exclusion criteria led to an exclusion rate of 9%. This indicates that the population of workers that was sampled was at high risk of CAD. This agrees

<table>
<thead>
<tr>
<th>Occupational stress index aspects</th>
<th>Men (n = 651)</th>
<th>Women (n = 338)</th>
</tr>
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<tbody>
<tr>
<td>High demand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High demand</td>
<td>2.06 (1.48–2.89)</td>
<td>0.65 (0.35–1.20)</td>
</tr>
<tr>
<td>Strictness</td>
<td>1.1 (0.87–1.47)</td>
<td>0.88 (0.45–1.71)</td>
</tr>
<tr>
<td>Conflict/uncertainty</td>
<td>1.7 (1.25–2.4)</td>
<td>1.11 (0.62–1.96)</td>
</tr>
<tr>
<td>Underload</td>
<td>2.71 (1.96–3.75)</td>
<td>3.48 (1.91–6.31)</td>
</tr>
<tr>
<td>Avoidance/symbolic aversiveness</td>
<td>1.32 (0.93–1.86)</td>
<td>0.69 (0.39–1.23)</td>
</tr>
<tr>
<td>Extrinsic time pressure</td>
<td>2.26 (1.46–3.47)</td>
<td>1.02 (0.45–1.2)</td>
</tr>
<tr>
<td>Aversiveness/noxious exposures</td>
<td>1.28 (0.92–1.79)</td>
<td>1.37 (1.19–1.70)</td>
</tr>
<tr>
<td>OSI total</td>
<td>1.58 (1.49–1.68)</td>
<td>1.15 (1.10–1.21)</td>
</tr>
</tbody>
</table>

OSI, Occupational Stress Index; CI, Confidence interval; dependent variable: arterial hypertension, binary logistic regression models: complete cases analysis by gender, odds ratios adjusted for age, OSI aspects were merged into one regression model analysis, and OSI total was analysed separately.
Disorders in middle-aged men and women

with the finding that nearly half of all adults in the United States have a chronic condition that is associated with an increased risk of cardiovascular disease: 45% of individuals who are 20 years of age and older have hypercholesterolemia, hypertension, or diabetes (Fryar et al., 2010). Another study in Mexico also showed that among adults over 40 years of age, the prevalence of undiagnosed diabetes is 6.5% and the

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<td>Odds ratios (95% CI)</td>
<td>P</td>
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<tr>
<td>High demand</td>
<td>1.23 (0.94–1.62)</td>
<td>0.11</td>
<td>1.77 (1.40–2.24)</td>
<td>0.01</td>
</tr>
<tr>
<td>Strictness</td>
<td>0.94 (0.64–1.39)</td>
<td>0.79</td>
<td>1.88 (1.18–3.00)</td>
<td>0.01</td>
</tr>
<tr>
<td>Conflict/uncertainty</td>
<td>1.09 (0.82–1.44)</td>
<td>0.52</td>
<td>2.96 (1.94–4.52)</td>
<td>0.01</td>
</tr>
<tr>
<td>Underload</td>
<td>1.27 (0.88–1.83)</td>
<td>0.19</td>
<td>4.71 (2.84–7.81)</td>
<td>0.01</td>
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<tr>
<td>Avoidance/symbolic aversiveness</td>
<td>0.85 (0.52–1.32)</td>
<td>0.50</td>
<td>2.75 (1.82–4.16)</td>
<td>0.01</td>
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<tr>
<td>Extrinsic time pressure</td>
<td>1.93 (1.06–2.56)</td>
<td>0.80</td>
<td>2.87 (1.46–5.61)</td>
<td>0.01</td>
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<tr>
<td>Aversiveness/noxious exposures</td>
<td>0.77 (0.62–0.95)</td>
<td>0.60</td>
<td>2.12 (1.30–3.44)</td>
<td>0.01</td>
</tr>
<tr>
<td>OSI total</td>
<td>1.21 (1.15–1.45)</td>
<td>0.01</td>
<td>2.40 (1.67–3.45)</td>
<td>0.01</td>
</tr>
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CI, Confidence interval; dependent variable: diabetes mellitus; binary logistic regression models: complete cases analysis by gender, odds ratios adjusted for age, OSI aspects were merged into one regression model analysis, and OSI total was analysed separately.

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<tr>
<td>High demand</td>
<td>1.41 (0.91–1.64)</td>
<td>0.07</td>
<td>0.972 (0.73–1.29)</td>
<td>0.84</td>
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<tr>
<td>Strictness</td>
<td>0.83 (0.66–1.04)</td>
<td>0.11</td>
<td>1.42 (1.03–2.03)</td>
<td>0.03</td>
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<tr>
<td>Conflict/uncertainty</td>
<td>0.95 (0.798–1.15)</td>
<td>0.65</td>
<td>1.41 (1.06–2.02)</td>
<td>0.02</td>
</tr>
<tr>
<td>Underload</td>
<td>2.11 (1.76–2.52)</td>
<td>0.04</td>
<td>3.26 (2.13–4.99)</td>
<td>0.01</td>
</tr>
<tr>
<td>Avoidance/symbolic aversiveness</td>
<td>0.79 (0.65–1.09)</td>
<td>0.06</td>
<td>1.00 (0.05–20.83)</td>
<td>0.99</td>
</tr>
<tr>
<td>Extrinsic time pressure</td>
<td>0.87 (0.65–1.16)</td>
<td>0.33</td>
<td>1.14 (0.08–1.88)</td>
<td>0.62</td>
</tr>
<tr>
<td>Aversiveness/noxious exposures</td>
<td>0.53 (0.39–0.72)</td>
<td>0.01</td>
<td>0.59 (0.38–0.91)</td>
<td>0.02</td>
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<tr>
<td>OSI total</td>
<td>1.31 (1.24–1.39)</td>
<td>0.01</td>
<td>1.54 (1.17–2.03)</td>
<td>0.01</td>
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CI, Confidence interval; dependent variable: dyslipidemia; binary logistic regression models: complete cases analysis by gender, odds ratios adjusted for age, OSI aspects were merged into one regression model analysis, and OSI total was analysed separately.

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<thead>
<tr>
<th>Occupational stress index aspects</th>
<th>Low HDL-C</th>
<th>High TC</th>
<th>High TG</th>
<th>High LDL-C</th>
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<tr>
<td></td>
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</tr>
<tr>
<td>High Demand</td>
<td>1.03 (0.82–1.28)</td>
<td>0.90 (0.73–1.11)</td>
<td>0.60 (0.31–1.14)</td>
<td>1.33 (0.92–1.92)</td>
</tr>
<tr>
<td>Strictness</td>
<td>1.22 (0.93–1.32)</td>
<td>1.05 (0.90–1.22)</td>
<td>0.74 (0.39–1.45)</td>
<td>1.25 (0.87–1.78)</td>
</tr>
<tr>
<td>Conflict/uncertainty</td>
<td>1.02 (0.81–1.27)</td>
<td>1.02 (0.82–1.25)</td>
<td>0.71 (0.37–1.35)</td>
<td>1.37 (0.95–1.97)</td>
</tr>
<tr>
<td>Underload</td>
<td>1.73 (1.40–2.12)**</td>
<td>1.70 (1.40–2.07)**</td>
<td>1.07 (0.56–2.02)</td>
<td>1.76 (1.22–2.53)**</td>
</tr>
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<td>Avoidance/Symbolic Aversiveness</td>
<td>1.23 (0.91–1.39)</td>
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</tr>
<tr>
<td>Extrinsic Time Pressure</td>
<td>0.68 (0.51–0.89)**</td>
<td>1.29 (0.96–1.37)</td>
<td>1.32 (1.10–1.59)**</td>
<td>0.71 (0.48–1.07)</td>
</tr>
<tr>
<td>Aversiveness/Noxious Exposures</td>
<td>0.61 (0.49–0.77)**</td>
<td>0.54 (0.44–0.68)**</td>
<td>0.40 (0.21–0.77)**</td>
<td>0.84 (0.58–1.23)</td>
</tr>
<tr>
<td>OSI total</td>
<td>1.39 (1.13–1.72)**</td>
<td>1.48 (1.22–1.80)**</td>
<td>1.14 (1.11–1.16)*</td>
<td>1.04 (0.73–1.49)</td>
</tr>
</tbody>
</table>

CI, Confidence interval; TC, total cholesterol; TG, triglycerides; HDL-C, high density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; binary logistic regression models, odds ratios adjusted for age, OSI aspects were merged into one regression model analysis, and OSI total was analysed separately. 

*P < 0.05, **P < 0.01.
prevalence of undiagnosed hypertension is 17.5% (Rojas-Martinez et al., 2012).

The occupational groups in the present study differed in terms of the prevalence of a CAD history and smoking. A substantial body of evidence links low socio-economic status and low education to an unhealthy lifestyle, psychosocial stress, and an increased incidence and prevalence of coronary artery disease (Wamala et al., 1999; Kuper et al., 2002). Smoking can confound associations of interest and is an important variable that could be included as an intermediate variable when investigating links between work stress and CHD. Work stress is currently not included in the American Heart Association list of established risk factors for CHD, but individual responses to stress are acknowledged to be potential contributing factors (www.americanheart.org). A large meta-analysis (Kuper et al., 2002) revealed associations between depression, social support, and psychosocial work characteristics, and CAD development and prognosis. Thus, occupation is a major socio-economic factor that affects health. It has been shown that prolonged exposure to stress at the workplace may directly affect the autonomic nervous system and neuroendocrine activity, thereby contributing to the development of hypertension and lipid disorders and increasing the incidence of DM (Nagaya et al., 2006).

Several plausible mechanisms that explain how long-term work stress may influence the risk of CHD have been suggested (Hemingway and Marmot, 1999). These include the prolonged overactivation and dysregulation of the autonomic nervous system and the hypothalamus-pituitary-adrenal cortex (HPA) axis. Both may increase disease risk, disrupt existing disease processes, and trigger acute events, such as heart attack, all of which can worsen the prognosis. Chronic stimulation of the HPA axis by depression frequently results in hypercortisolemia, blunted HPA activity, and diminished feedback control, as evidenced by non-suppression of cortisol secretion after dexamethasone suppression. Hypercortisolemia is associated with the suppression of growth and sex hormones (Rozanski et al., 2005). Various lines of data suggest that there are links between chronic psychological distress and certain adverse behaviours, such as overeating and smoking. Enhanced physiological reactivity to acute stress is clinically important as it is linked to subclinical atherosclerosis (Dallman et al., 2004).

Stress is also believed to drive susceptible persons towards the metabolic syndrome, which is characterized by insulin resistance, lipoprotein disturbances, reduced fibrinolysis, and central obesity; it is also believed to accelerate cellular ageing (Epel et al., 2004). In addition to these and other direct biological effects, work stress may influence CHD risk indirectly by increasing health-risking behaviour (Kivimäki et al., 2006), lowering help-seeking behaviour, and reducing compliance with medical treatment (Hemingway and Marmot, 1999).

It is unclear whether the increased risk associated with workplace stress seen in some studies is due in part to direct effects of chronic stress on insulin resistance, resting blood pressure, and lipoprotein metabolism, or whether it reflects the effects of specific aspects of occupational stress. The latter notion is supported by Whitehall II and other studies (Brunner et al., 2002; Chandola et al., 2006). In the present study, work stress was characterized by multiple parameters, which allowed us to study the association between coronary risk factors not only with the total OSI score but also with particular OSI aspects. The links between the OSI aspects and hypertension, lipid disorders, and DM prevalence were assessed in different occupational groups. The occupational groups varied significantly in terms of the prevalence of hypertension, dyslipidemia, and DM type 2 (Table 1). They also varied significantly from each other with regard to the OSI aspect scores and the total OSI scores (Table 1).

There were significant correlations between the different OSI aspects, as shown in Table 2. This makes it difficult to isolate the independent effects of the OSI aspects on the disease outcome risk. In turn, this suggests that a prospective study design should be used in future investigations.

Work-related risk factors include both physical and psychosocial elements. Karasek (2006) showed that individuals who suffered more ‘job strain’, namely those who were under pressure to work hard or quickly but who had less control over that pressure, had a greater risk of cardiovascular disease. The case–control study by Schnall et al. (1990) also showed that ‘job strain’ is a risk factor for both high blood pressure and structural changes in the heart (left ventricular hypertrophy) in male workers. These studies were among the first to show that work organization can affect the degree of cardiovascular risk. Many other studies support the link between job strain and cardiovascular disease. Ambulatory blood pressure levels have been shown to increase in work situations with high job strain, either directly or because of behaviour modifications, and to contribute in general to the development of cardiovascular disease (Jovanović and Jovanović, 2004; Radi et al., 2005). Similarly, in the present study, Underload (which refers to homogenous and simple job tasks,
working alone without any communication with others, automatic decision from input, lack of recognition of good work, inadequate pay, and no promotion prospects) was associated with a 2.71–3.48-fold increase in arterial hypertension in both sexes (Table 3). Total OSI also associated significantly with arterial hypertension in both sexes. By contrast, High Demand, Conflict/Uncertainty, and Extrinsic Time Pressure contributed significantly to arterial hypertension in men only. A study that was similar to ours on occupational stressors and hypertension in transit operators also found that working stressors significantly affected hypertension; however, it did not detect significant gender differences in terms of the association between particular stressors and hypertension, probably because few women were in the sample (Greiner et al., 2004). The gender-related differences in associations between OSI aspects and arterial hypertension that we observed suggest that conflict and a need to speed up performance affect only male workers. However, the occupations that were examined were heavily dominated by one gender or the other (Table 1), which means that these apparent gender differences may actually indicate differences in occupation. This makes it difficult to draw conclusions about the relationship between gender, occupational stress, and arterial hypertension. Further research is needed to resolve this issue.

The incidence of DM type 2 is increasing rapidly worldwide. Previous studies have found associations between DM type 2 psychosocial stressful life events, and depressive symptoms (Golden et al., 2004; Norberg et al., 2007). Investigators in the Whitehall II Study showed that effort–reward imbalance and low social status, but not low job control or high job demands, were associated with incident DM type 2 (Heraclides et al., 2009). By contrast, two cross-sectional studies that applied the Karasek model detected associations between low job control and DM type 2 in women (Agardh et al., 2003). In the present study, other OSI aspects and total OSI along with low job control and high job demands associated significantly with DM in female workers (Table 4). Underload exhibited the strongest association with DM in women. This can partly be explained by a low sense of coherence (SOC) in these workers. SOC is the capacity to cope with stressors, and a previous study has shown that a low SOC is associated with DM type 2 in women (Agardh et al., 2003). Underload may reduce the strategies with which a worker can cope with problems and thus could promote susceptibility to disease. Bearing in mind the child-bearing role of women and their traditional roles in childcare and domestic management, it may be that the SOC components (including comprehensibility and manageability) are more developed in women than in men, and this may have elevated their ability to cope with occupational stressors, as measured by particular OSI aspects. However, in Underload, women without family, children, or emotional support may suffer from the lack of social recognition and loss of meaningfulness, and this may predispose them to neuroendocrine stress and reduce their ability to cope with occupational stressors. Another possible explanation for the association between the female gender, DM, and occupational stress is provided by a study in Sweden that showed that compared to men, Swedish women still do as much work in the house and perform more childcare on a weekly basis (Berntsson et al., 2006). Thus, women today must shoulder two areas of responsibility, which may explain, at least in part, the greater impact of work stressors on the diabetes risk of women. The increase in DM due to work stress and low emotional support may be mediated by both harmful lifestyle habits and biological mechanisms such as the activation of the neuroendocrine pathways (Rosmond and Björntorp, 2000). It has been suggested that stress may lead to disease as a result of abnormal cortisol secretion patterns that are due to frequent or persistent challenges of the HPA axis that can occur more often in women (Brunner et al., 2002). In chronic stress, this pattern may change so that the levels of cortisol are not elevated upon awakening, and/or fail to return to baseline within a period of several hours.

In men, DM is associated with overall OSI but not with particular OSI aspects (Table 4). Thus, work stress and low emotional support easily increase the risk of DM type 2 in women than in men. This observation furthers our understanding of psychosocial stress as a potential risk factor for DM type 2 in women. One study has suggested that body mass index (BMI) is more strongly associated with future DM risk in men than stress factors (Golden et al., 2004). However, the prospective study of Chandola et al. (2006) showed that while employees with chronic work stress were more than twice as likely to develop metabolic syndrome than those without work stress (OR 2.25, 95% CI 1.31–3.85), pre-existing physiological risk (obesity) and the social gradient were unlikely to explain this association. That particular aspects of work stress (such as Underload and Conflict/Uncertainty) more greatly increase the susceptibility of women, but not men, to DM than that suggested by overall OSI that gender may account for this association. However, given that the studied occupational groups consisted almost
entirely of either women or men, it may be that the association between DM, the female gender, and specific OSI aspects reflects differences in occupation rather than gender.

Altered adrenocortical function and increased cortisol output can influence hepatic lipoprotein metabolism and insulin sensitivity in target organs (Macfarlane et al., 2008). Low concentrations of HDL cholesterol, increased LDL cholesterol levels, and high TG levels as well as glucose intolerance have been linked to a high basal secretion of cortisol (Arnaldi et al., 2010). In the present study, the employees as a group showed positive associations between a high Underload score and low HDL cholesterol, high TC, and high LDL cholesterol levels (Table 6). Total OSI also associated significantly in a positive fashion with low HDL cholesterol, high TC, and high TG levels. Interestingly, Aversiveness/Noxious Exposure (namely isometric lifting, vibration, heat, cold, or noxious exposure) was associated with a reduced occurrence of low HDL cholesterol, high TC, and high TG levels (Table 6). This suggests that mental and emotional stressors may play different pathogenetic roles compared to physical work, which in turn could explain the inconsistencies between studies evaluating stress and lipid disorders. That cholesterol levels, but not TG levels, correlate positively with cardiac reactions and mental stressors supports the notion that total OSI, and especially Underload, plays significant roles in the development of cardiovascular disease (van Dooren et al., 1998).

Occupational stress has been associated with reduced leisure-time physical activity (Kouvonen et al., 2005). Societal development in terms of labour-saving devices, the reduced need for physical activity at work and during leisure time, and the broad availability of energy-dense foods, together with the biological adaptation to store fat in times of famine, means that people are increasingly becoming obese. Moreover, adipocytes are more than passive repositories for fat. Research is increasingly indicating that the adipose tissue is actually an endocrine organ that interacts with many systems (Schulte et al., 2008). The present study detected negative associations between Aversiveness/Noxious Exposures and lipid disorders in both genders (Tables 5 and 6). This could explain why physical demands of either an isometric or an isotonic type could positively impact lipid disorders, especially in ones with high total OSI and reduced leisure-time physical activity. Traditional occupational hazards, such as exposure to toxic chemicals, cold, and noise, may account for only part of the effect of work on health. Work stress refers to aspects of work design, organization, and management, and their social and organizational contexts that have the potential to harm employee health. This paradigm, in addition to the conventional physicochemical approach, could form an essential part of contemporary occupational health research (Kivimäki et al., 2006).

In addition to the strong, consistent evidence of an association between exposure to job strain and CVD, especially among men, many other elements of causal inference, particularly biological plausibility, support the claim that job strain is indeed a major CVD risk factor. The limited data that currently exist generally show that workplace interventions that increase decision-making latitude or diminish psychological demands (such as by reducing time pressure) result in favourable changes in mediators that are relevant to the cardiovascular system, such as blood pressure or the catecholamine and lipid profile (Belkic et al., 2004). The present study also revealed a significant relationship between total OSI and CVD risk factors as well as gender-related differences in terms of particular OSI aspects and clinical outcomes (Tables 3–6). A meta-analysis by Kivimäki et al. (2006) revealed that most studies detected an insignificant inverse association between job strain and CHD in females. Differences in the questionnaires that were used may explain this inconsistency between previous studies and ours. Thus, further research on the modern work life is needed to clarify the role of work stress in the etiology of CHD.

### Strengths and weaknesses of the study

One of the strengths of the study is the careful selection of the sample, which resulted in a suitably representative worker population, a high response rate, and a sample size with sufficient power. This required the application of carefully defined exclusion criteria. Moreover, the exposure variables were assessed by using a validated questionnaire that involved anonymous self-rating and a control system that allowed missing values to be completed. In addition, the outcome variables were defined by explicit diagnostic criteria and were determined by using medical records kept by professional health workers at the worksite clinic. There were also adjustments for age and stratification by gender.

There are several potential confounders whose data were not available in regression analysis. Obesity/body mass index, socio-economic level/education, and dietary habits were not assessed, although they could affect particular OSI aspect associations with hypertension, dyslipidemia, and DM. In addition, the statistical merging of the occupational groups makes...
it difficult to determine whether it is the occupation per se or the OSI aspect that is responsible for particular associations. The OSI offers a potential solution to this problem as it provides occupation-specific instruments that are mutually compatible in the theoretical framework of OSI since it allows between-occupation comparisons. Meanwhile, the General OSI Questionnaire can be used for between-occupation comparisons, especially when evaluating a heterogeneous working population with a wide range of profiles. The occupation-specific instruments are more operationalized than a single generic instrument and are therefore especially helpful when key modifiable stressors in a given work environment are to be identified. Moreover, general questionnaires share a common weakness in their remoteness from actual work experiences. While the internal consistency of the total general OSI is within the desired range (Cronbach alpha = 0.81), the two aspects from the General OSI that have low internal consistency are Extrinsic Time Pressure and Strictness (Landsbergis and Theorell, 2000).

Much of the occupational exposure data, especially from longitudinal studies, have been gathered from full-time working persons with some degree of occupational stability. The exclusion of temporary workers, who are likely to be exposed to significant job strain, could reduce risk estimates. Due to the cross-sectional design of the present study and the possible confounders for which adjustment was not possible, causal inferences should be made with caution.

CONCLUSIONS

The present study provides evidence for the association between work stress and metabolic disorders and hypertension. The total OSI associated significantly with DM type 2, arterial hypertension, and dyslipidemia in both genders. Different OSI aspects varied in terms of gender- and occupation-specific patterns. Of all the OSI aspects, Underload, which reflects lack of social communication, simple task preparation, and underestimation of work output, associated most strongly with metabolic disorders and hypertension in both sexes.

Acknowledgements—No conflicting interests are declared.

REFERENCES


